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INSTITUTE OF OCEAN SCIENCES, PATRICIA BAY

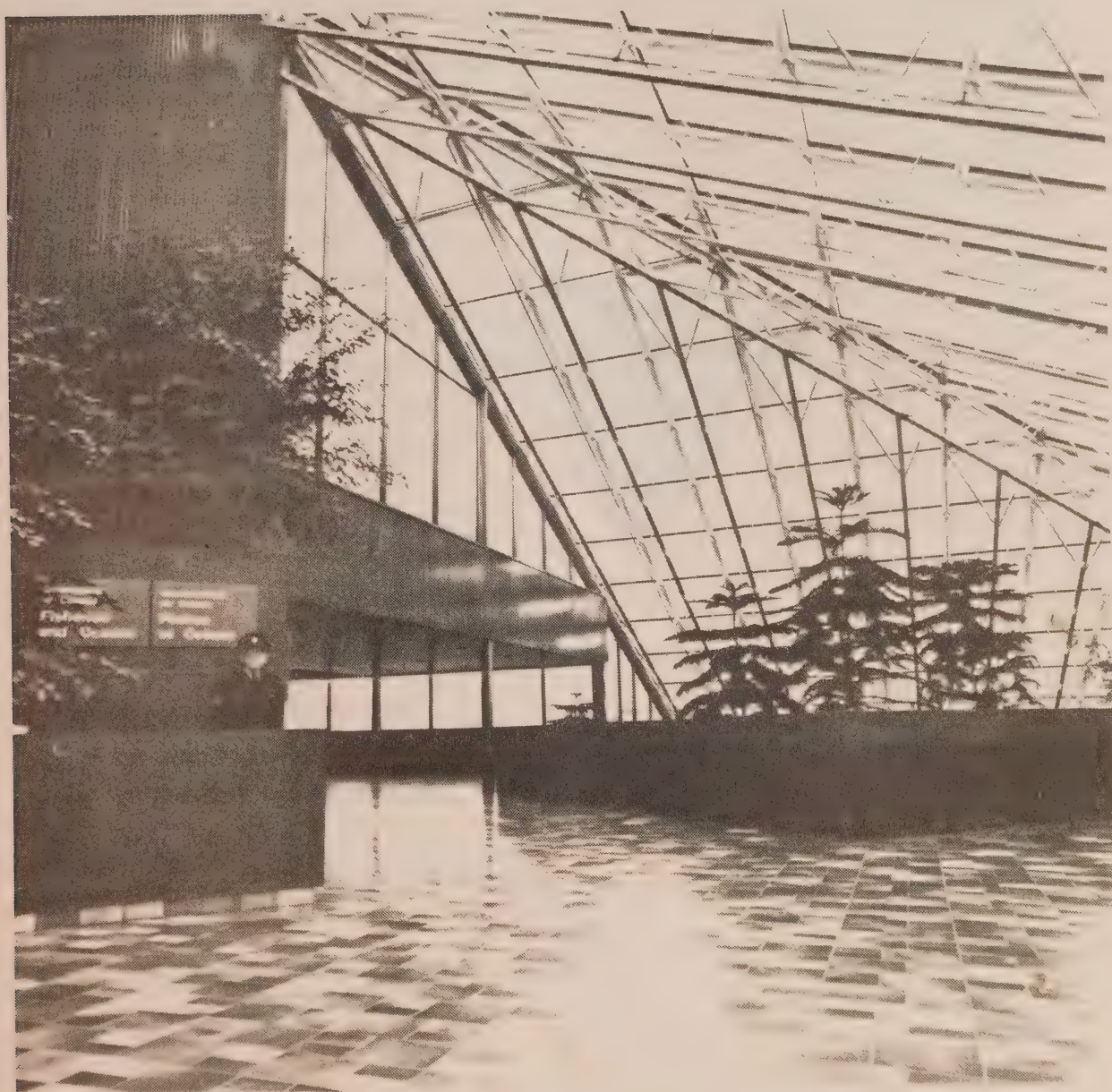
ANNUAL REPORT - 1978

Canada
INSTITUTE OF OCEAN SCIENCES, PATRICIA BAY
Sidney, B.C.



INSTITUTE OF OCEAN SCIENCES, PATRICIA BAY

ANNUAL REPORT 1978



Sidney, B.C.

March, 1979



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DIRECTOR-GENERAL'S OFFICE

R.W. Stewart

T. Van Dusen - Secretary

A.B. Cornford

The end of 1978 sees members of the Institute of Ocean Sciences at last settled into their fine new quarters. It also sees them more and more working as an Institute, as the rather pachydermal shells, appropriate to the separate existence that groups formerly had, become replaced by more permeable membranes appropriate to our new physical togetherness. The increased effectiveness of our work arising from this integration was the rationale behind the expenditure of \$20,000,000 of the taxpayer's money on the construction of the facility. As dreams have become reality, one senses that the faith, energy, and initiative of the many people who made this Institute possible, are being justified.

The fiscal restraints of the times have made our work more difficult, and leave everyone with a very cramped feeling. This feeling is not helped by a general realization that things are likely to get worse before they get better. Nevertheless, as this report indicates, we retain a substantial capability, and have been applying this capability to problems we perceive as being important. The fact that this report is replete with references to new instruments and new techniques shows that while our diet has become a spartan one, it has not yet reached the stage of starvation. Our long-standing efforts to work with the private sector through the Make-or-Buy policy have paid off, at times almost spectacularly, in the way in which private companies are conducting work of direct interest to us, but largely funded by non-Institute funds through the unsolicited proposal route.

It is interesting to note that despite the general sense of disillusion with the national and provincial economy, chart sales this year bounded upward to an unprecedented figure, following several years of stagnation. Perhaps a portent of a more prosperous future?

Again this year, *Pandora II* was able to get into the Arctic and achieve a substantial surveying job. Nevertheless, one continues to feel there must be a better way than having to fight the waters off the north coast of Alaska twice every year and give up the whole summer of a major ship in order to get in a couple of months of survey.

We were even able to maintain some presence on the international oceanographic scene. At year-end *Parizeau* was on her way towards her equatorial station, to take part in the great Global Weather Experiment (First GARP Global Experiment). The year-end also saw a remarkable cooperative effort in which a side-scan-sonar team put together by Hydrographic Division and Ship Division, together with an Armed Forces diving team, were able to recover an Oceanographic Division instrument from the bottom of English Bay -- just in time to put it aboard *Parizeau* for use on the equator. That we are able to respond promptly and effectively to unforeseen circumstances leaves a gratifying feeling of vigorous life.



Prime Minister, Pierre Trudeau with Frank Chambers, Pisces IV pilot, inspecting the submersible while it was on display at the Canadian National Exhibition, 1978.

HYDROGRAPHIC DIVISION

M. Bolton - Regional Hydrographer

D. van Aanhout - Secretary

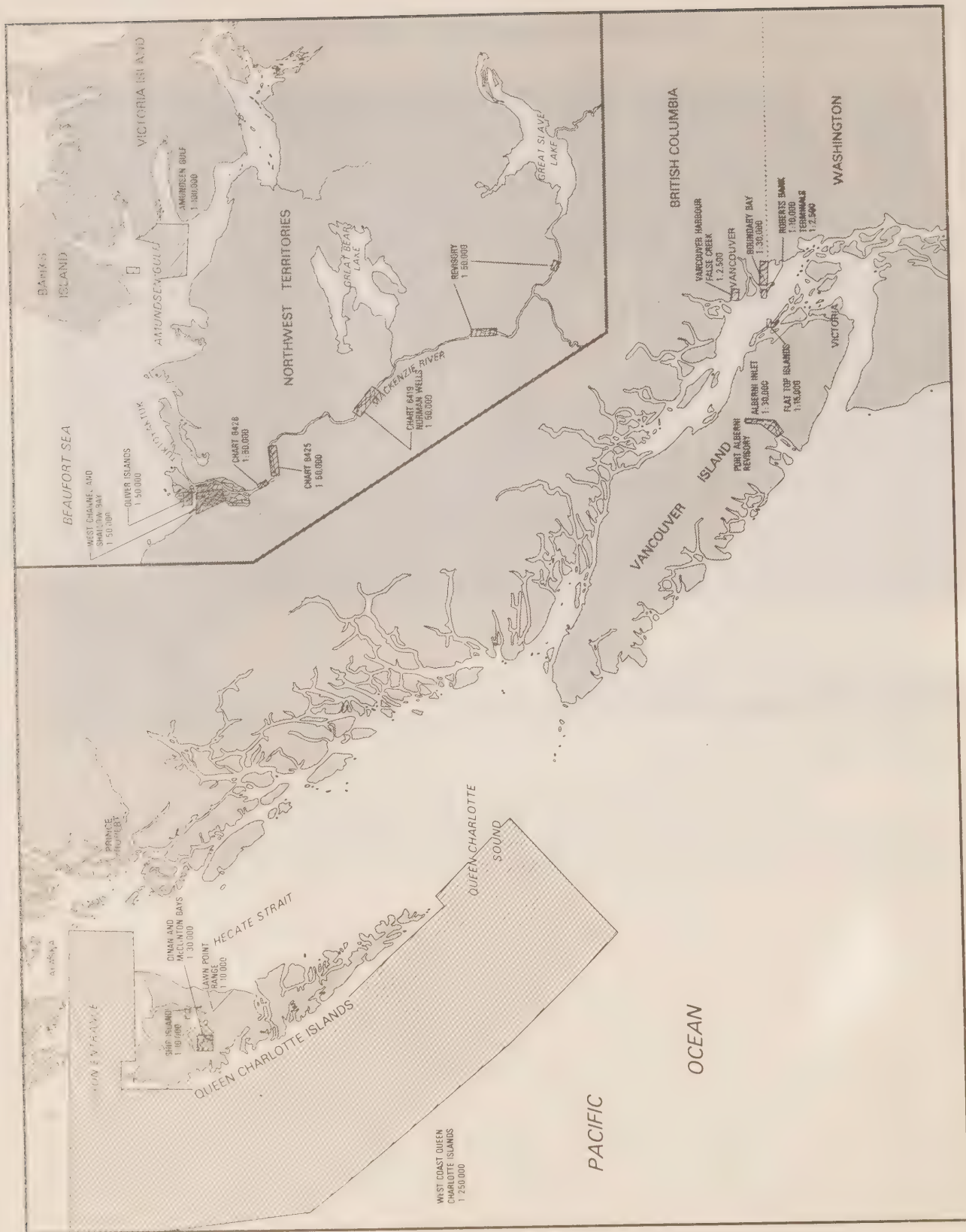
This was a year of consolidation and adaptation to the excellent facilities at the Institute of Ocean Sciences. As was anticipated, some minor adjustments were necessary but, in the main, the staff and the Institute fitted remarkably well.

A highlight of the year was hosting the 17th Annual Canadian Hydrographic Conference at Patricia Bay in April. Over three hundred delegates attended, including representatives from eight foreign hydrographic organizations. The wind-up luncheon was addressed by Rear Admiral Steve Ritchie, President of the Directing Committee of the International Hydrographic Organization, who spoke on "The Widening Horizons of Hydrography".

The design, development and installation of an extendible transducer aboard M.V. *Pandora II* under severe time constraints was a major factor in the successful completion of arctic surveys in Amundsen Gulf. Multi-disciplinary surveys off the B.C. west coast were again conducted, as were the ongoing surveys on the Mackenzie River and Delta.

The establishment of a Technical Records Unit in Chart Construction, in which all hydrographic documents are consolidated has considerably advanced the service for all users. The demand for charts continues at a high level and this year, for the first time, over 200,000 charts were distributed.

Computing Services continued to upgrade systems associated with the UNIVAC 1106, consequently the workload continues to increase with outside (non-OAS) users representing about 18% of the total volume.



Field survey operations, 1978

FIELD HYDROGRAPHY SECTION

R. Wills - Regional Field Superintendent

F.A. Coldham	M.L. Preece
J.V. Crowley	A.R. Raymond
K.L. Czotter	G.E. Richardson
G.H. Eaton	E.D. Sargent
B.M. Lusk	R.U. Schoenrank
*A.B. Manley	C.R. Tamasi
R.I.D. May	+W.P. Van Duin
P.R. Milner	J.A. Vosburgh
A.R. Mortimer	M.M. Ward
A.D. O'Connor	D.J. Wood
R.D. Popejoy	M.V. Woods

*Left during 1978

+Joined during 1978

R.W. Sandilands - Head, Sailing Directions
*J.W. Chivas
+A. Smith
L.M. Wakefield

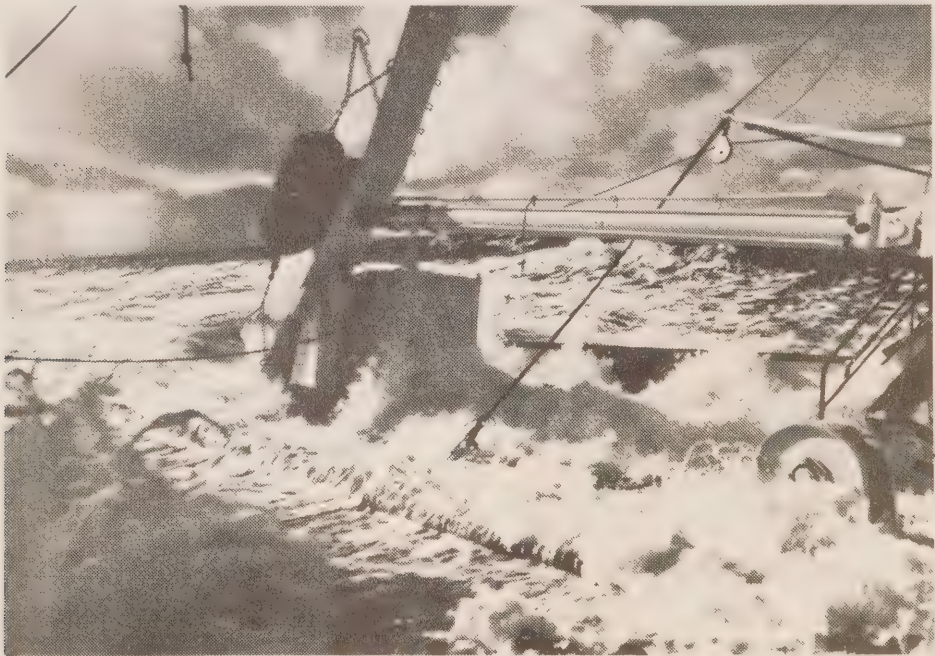
J.B. Larkin - Head, Hydrographic Development
A.J. D'Aoust
**K.L. Czotter
**M.L. Preece

**Rotational Staff in Hydrographic Development.

The main hydrographic work on the B.C. Coast in 1978 was carried out by a large party with Mr. B.M. Lusk in charge. Surveys of Vancouver Harbour (False Creek), Roberts Bank Superport, Tsawwassen, Boundary Bay, Alberni Inlet and the Flat Top Islands area were completed. All but Vancouver and vicinity had been last surveyed in the 1930's well before the use of echo sounders. Offshore multi-disciplinary surveys were carried out by C.S.S. *Parizeau* off the west coast of the Queen Charlotte Islands from the Scott Islands north to the Alaska border during the period 4 July to 14 August. For the first time in this region a new Marconi Sat. Nav. and Austron Loran-C were employed for precise positioning, eliminating the need to establish shore installations, apart from electronic positioning sites used for calibration purposes. The prime purpose for the cruise was the collection of gravity data but complete magnetic and seismic coverage was conducted as well as standard bathymetry. Considerable effort has been made by the Hydrographic Service off the West Coast during the years 1973, 1975, 1976 and 1978 contributing toward the joint D.F.O./E.M.R. natural resource charting

program. A small area in Hecate Strait is all that remains to be covered in the nearshore zone.

C.S.S. *Richardson* was employed on hydrographic surveys somewhat greater in extent than has been usual for her in recent years. A small party with Mr. J. Vosburgh in charge completed a number of outstanding projects including new surveys of Sabine Channel and False Bay, and in the Queen Charlotte Islands, Lawn Pt. range, and the vicinity of Ship Island in Masset Inlet. Work in Masset Inlet also included surveys of Dinan Bay and McClinton Bay which were previously unsurveyed. At season's end additional revisory work was carried out in Barkley Sound, Port Alberni (Somass River) and the Port Moody, Indian Arm area of Vancouver Harbour. Consistent with the practice in recent years, major revisory surveys in southern areas were carried out by contract.



Stern of Pandora II awash during surveys in Amundsen Gulf

Even though plagued by bad weather and rough seas, Mr. A.D. O'Connor's party on *Pandora II* had another successful season in the Western Arctic. Multi-disciplinary surveys of the main area of Amundsen Gulf were completed since ice conditions prevented sounding in the primary area in eastern Beaufort Sea. In the course of these operations a hydrographer was detached to work on a levelling project for the Geodetic Survey of Canada in the Mackenzie Delta. *Pandora II* served adequately as a major survey ship. Her sounding capability, previously found wanting, has been firmly established with the installation of an extendible transducer. It performed well under all conditions encountered and the success of the cruise can be directly attributed to it. The portable hydrographic acquisition system (PHAS) performed well this season and Pagecom F.M. radio pagers were

used to advantage in conjunction with it. The wind generator was again used to keep shore station batteries charged all season, and for the first time in this area, expendable sound velocimeters (X.S.V.) manufactured by Sippican Corporation, were used to determine velocity corrections to our echo sounders.



R.P.S. beacon and wind generator installed on Victoria Island

The charter vessel *Radium Express*, with Mr. J.V. Crowley in charge, continued the Athabasca-Mackenzie Waterway survey program. Surveys were completed of shoal areas at km 283, and at km 492 and 562 where sand bars had encroached on established ranges. Sounding was also completed near Norman Wells for chart 6419. Surveys were carried out in Shallow Bay and its approach channels, and the survey of West Channel was completed. The annual revisory survey of the Mackenzie River was also completed, as was the photographic surveillance of artificial islands in the Beaufort Sea.

Mr. A.R. Mortimer continued his studies of the Canadian West Coast Loran-C chain. This included a cruise on C.S.S. *Parizeau* in November to make cycle identification tests at the approaches to Juan de Fuca Strait, where signal reception problems exist. Adequate data was collected to define the lattice shift for charts of Dixon Entrance/Hecate Strait and Queen Charlotte Sound. Development work continued on a Sat Nav, Loran-C based integrated navigation system. Dr. Dave Wells from Bedford Institute of Oceanography worked throughout the Juan de Fuca cruise developing programs for the integrated system and created a system capable of positioning *Parizeau* on the forthcoming First Garp Global Experiment cruise.

Sailing Directions

The second edition of B.C. Small Craft Guide, Volume II, Boundary Bay to Cortes Island was published in April. The coverage of this volume has been extended beyond that of the first edition and now includes Prideaux Haven and the designated marine park area of Desolation Sound, an increasingly popular area for recreational boaters. The seventh edition of B.C. Coast Sailing Directions, North Portion, Volume II was published in July and new editions of B.C. Sailing Directions, South Portion, Volume I and B.C. Small Craft Guide, Volume I are under preparation.

The Sailing Directions for Kootenay Lake and River which are printed to accompany chart 3050 were revised and passed to the Chart Compilation section which has the chart in production. The section also participated in a contract for revisory surveys and obtained revision material on the southern B.C. waters.

Hydrographic Development

A. D'Aoust moved to Ottawa in early summer to work full time on the Aerial Hydrography Project at Canada Centre for Remote Sensing. As a result of an unsolicited proposal, a review of the project was made, and specifications for a contract have been prepared. It is anticipated that the contract will be let early in 1979, and is scheduled for completion in eighteen months.

Hydrographers K. Czotter and M. Preece joined the section for their rotational assignment, and their major effort was directed to computer program development. Field sheet drawing programs were modified extensively to take advantage of some features of the Kongsberg flatbed system as well as to improve the visual quality of the field sheet. The section assisted hydrographers in preparing field sheets on the flatbed plotter before the survey season and final field plotting and title application in the fall. K. Czotter took several "breaks" during the year. He joined East Coast hydrographers in August for the Eastern Arctic Survey on board CCGS *John A MacDonald*, and attended the Hydrography II course in Ottawa for six weeks late in the fall.

Survey program packages were written for, and implemented on the HP67/97 hand held programmable calculators, the HP 9825 desktop calculator, and the DEC PDP-11 computer. Assistance was provided in assembling and checking the region's horizontal control data in preparation for inclusion in a geographic data bank.

J. Larkin and A. D'Aoust attended a Coastal Mapping Symposium in Rockville, Maryland in mid-August, and J. Larkin also attended the Fifth Canadian Symposium on Remote Sensing in Victoria during the last week of August.

CHART CONSTRUCTION SECTION

*F. R. Smithers - Regional Chart Superintendent
W. S. Crowther - A/Regional Chart Superintendent

R. Bell - Supervisor New Chart Production	*W. Lyons
P. Browning	P. Morton
G. Chan	G. Neilson
*D. Clark - Supervisor Chart Correction	R. Parker
W. S. Crowther - Production Chief	M. Patton
D. Dobson	A. Philp
E. Earl	L. Pickell
M. Farmer	R. Pierce
D. Fisher - Supervisor Chart Sales	A. Ross
+J. Gould	N. Said
+D. Harrison	+J. St. Gelais
M. Hohl	R. Taylor
K. Holman - Supervisor Chart Revision	*M. Taylor
+S. Huggett	L. Thompson
K. Josephson	B. Watt
R. Korhonen	+G. Whincup
D. Kynoch	
A. Lyon	

+Joined during 1978

*Left during 1978

1978 was a year of shake-down and adjustment for the Chart Production staff. New equipment, new surroundings and new programs helped to create an invigorating work environment.

The main efforts were directed to establishing a Technical Records Unit, maintaining chart stocks, and continuing the metrication program in accordance with national priorities.

Establishing the Technical Records Unit proved to be a larger than expected task. Nevertheless, the consolidation of all Field Sheets, Field Notes, Files and Chart Reproduction material in one location, under one responsible person provides efficient service to all users. This consolidation was necessary to maximize the control and utilization of all official records and documents.

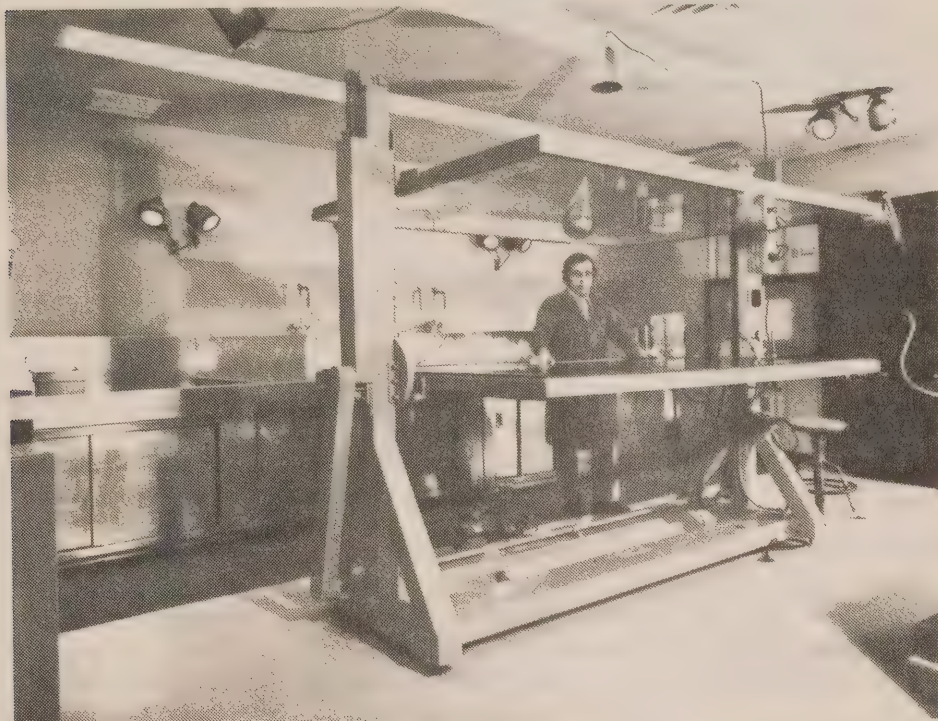
Maintaining chart stocks was not a simple task in 1978. This was our largest volume year ever. The total number of charts distributed exceeded 210,000, and hand amendments reached 1,765,000. In addition, seventy dealerships were inspected, one Class 'A' dealership in this Region became a reality, and nineteen new dealerships were established.

Emphasis on metrication continued in new Chart Production. In all, eight new charts of the bilingual-metric format were printed and a total of fifty-six new editions were printed of which eighteen were bilingual. Stock depletion necessitated nineteen reprints. To minimize costs and to expedite amendments to existing stock, three overprintings were undertaken. Twelve chart patches were prepared and printed, sixty Notices to Mariners were issued and ten Notices to Shipping were also processed.



Technical Records Unit

Graphic arts services continued to be provided on an as-available basis as continuing reprographic services for the Institute as a whole. The installation of the large vacuum frame in the Photo Mechanical Unit has greatly enhanced the quality of contact reproduction.



New Douthitt Vacuum Frame in Photo-Mechanical Unit

The Cartography 1 Training Course held at Ottawa was successfully completed by four cartographic staff in 1978. Four cartographic staff attended the Canadian Cartographic Association Conference held in Vancouver in June. The last cartographer to move from H.Q. as a result of decentralization arrived in Pacific Region this summer.

Conferences have become a regular occurrence at the Institute of Ocean Sciences. As part of the ongoing efforts to make available information regarding the work of the Institute, personnel from Chart Production often provide graphic arts services. Of particular note, the Map Librarians on a tour recently showed a keen interest in the Canadian Hydrographic Service, its history, as well as its production procedures and techniques.

Chart Production, assisted by Sailing Directions, hosted a large gathering of Power Squadron members in April. A total of 125 were treated to a film, lectures on navigation, advice on MAREP reporting and a lengthy tour and explanation of hydrographic chart production procedures and techniques. Power Squadrons submitted 430 MAREP reports affecting West Coast charts during 1978.

The Pacific Region Chart Production Section now has the capability of doing its own photohead plotting of mathematically generated graphics, and has integrated a GOMADS graphics editing and digitizing system into the chart production processes. The systems were brought on line by the Computer Services section.

Production & Distribution Statistics, 1978

New Charts published	8
New Editions published	56
Reprints published	19
Overprinting of existing chart stocks	3
Notices to Mariners issued	60
Notices to Shipping processed	10
Chart patches printed	12
Chart corrections (hand amendments)	1,765,000
Total charts distributed	210,000
Dealerships inspected	70
New Dealerships established	19
Dealerships withdrawn	0
MAREPS processed	430

TIDAL AND CURRENT SURVEY SECTION

W. J. Rapatz - Acting Regional Tidal Superintendent

A.B. Ages - i/c Hydraulic Research	W.S. Huggett - i/c Current Surveys
R.E. Brown	*J. Logan
*J. Bruce	A. C. Ma
*C.C. Carracedo	*J. J. Manson
W.R. Crawford - i/c Tidal Research	*K. Narayanan
A.N. Douglas (Computing Services)	A. J. Smedley
+G. Ellison	F. E. Stephenson - i/c Tidal Survey
W. J. Harris	M. J. Woodward
F.V. Hermiston	A. L. Woollard (Computing Services)

*Left during 1978

+Joined during 1978

The major tidal and current field survey in Johnstone Strait and Queen Charlotte Strait was completed early in 1978. As a result of this survey one reference current station and ten secondary stations have been added to Volume 6 (1980) Tide and Current Tables. The current observations from this survey are being prepared for publication in 4 volumes.

Work continued on an atlas of surface currents in Juan de Fuca Strait and the Gulf Islands. Surface currents in Juan de Fuca Strait were further investigated by carrying out several launch and air surveys, with assistance from the Remote Sensing Group. These surface currents are much more complex than was originally thought and further measurements must be carried out before the current atlas can be completed.

In the Fraser River, detailed measurements were made of salinities, temperatures and currents in and near the toe of the salinity wedge. The upstream limit of the salinity wedge was determined for a variety of discharges and tidal ranges.

In co-operation with the Water Quality Branch of Inland Waters, 24-hour time series of currents, salinities and temperatures were carried out at a number of stations between Steveston and New Westminster. Current measurements and salinity observations were also made in the North Arm and Canoe Pass area. A tide gauge was operated at the mouth of the North Arm for 12 months to provide the numerical model with a more accurate boundary condition. This computer model of tide heights in the Fraser River continued to be used by various government agencies and by private industry.

To examine the predictions of a previously developed oilspill computer program, a number of 24-hour surface flow measurements were made in Juan de Fuca Strait. These measurements were made from shipboard and by aerial reconnaissance in co-operation with the Remote Sensing Group. New equipment to track electronic oilspill markers was successfully tested.

A numerical model of Burrard Inlet was developed. Field measurements were made at the entrance to Burrard Inlet but more field measurements, particularly in winter months, are needed to properly calibrate the model. Useful boundary conditions for the model have yet to be determined.

Research on long period tides was conducted. The Solar annual (Sa.) and Solar semi-annual (Ssa.) tides for ports in Canadian waters were analyzed and the amplitudes and phase angles obtained were submitted for inclusion in the prediction process for Canadian Tide Tables. Research was also carried out into monthly and fortnightly tides.

A tide and current survey of Dodd Narrows and Porlier, Active and Gabriola Passes was conducted to improve current predictions for these locations. Tide gauges were deployed at both ends of each pass to determine the hydraulic head. Several months of current observations were carried out to construct and calibrate an empirical model showing the relationship between current and hydraulic head. All field work, with the exception of final recovery of the tide gauges (January 1979), was completed. Analysis of the data is still in progress.

The tsunami warning system gauge at Langara Island was destroyed in October 1977 by a large wave and was not fully operational again until almost a month later.

The records obtained at 24 permanent tidal stations and 6 long-term temporary stations operating on the Pacific Coast and in the Western Arctic were routinely processed, digitized and the data sent to the Marine Environmental Data Service in Ottawa. The new data processing system is now fully operational. This has resulted in reduced processing time and a higher quality of processed data. Work was started on further improving the data processing system by converting it from a magnetic tape to a disc-oriented data storage system.

Aanderaa gauges installed at Tuktoyaktuk, Cape Parry and Cambridge Bay in August 1977 were recovered. The data collected by these instruments have been processed and are now being analyzed. A detailed comparison will be made between these data and the data collected by the permanent water level gauge operated at these locations. The results of this investigation will be distributed as a report in 1979.

TSUNAMI ADVISER

S.O. Wigen

Present studies have shown that tsunamis have occurred fairly frequently on the Canadian west coast, and more than 20 have been recorded by the tide gauge at Tofino. These records are being studied in order to determine the frequency with which damaging tsunamis may be expected, and to prepare guidelines on advisable precautionary measures. Particular attention is being given to the Port Alberni area, which sustained considerable damage in 1964.

A federal-provincial working group has been formed to bring about improvements in tsunami warning procedures in British Columbia including the development of public education programs on the hazards of tsunamis and appropriate responses when one is occurring. A Canadian working group has also been formed to develop a joint Canadian-U.S. report on use of satellites in the International Tsunami Warning System. This report was requested by the International Co-ordination Group for the Tsunami Warning System in the Pacific and is in final stages of preparation.

COMPUTING SERVICES SECTION

K. Teng - Head

R.E. Johns	A.L. Woollard - Tides and Currents
D.B. Smith	+M.E. Woodward - Frozen Sea Research Group
J.W. Butcher	*A. Wharton - Frozen Sea Research Group
A.N. Douglas - Tides and Currents	+E. Wong - Offshore Oceanography
M.G. Foreman - Numerical Modelling	*P. Lacroix - Offshore Oceanography
*S.R. Oraas	+S.J. Szalai - Management Services
J.S. Page - Ocean Chemistry	*R.G. Hlady - Management Services
P.J. Richards - Numerical Modelling	*G. Silver - Hydrography

+Left in 1978

*Joined in 1978

Univac 1106 Computer System

1978 was primarily a year of consolidation for the Institute's Univac 1106 Computer System, featuring minimal hardware changes but considerable activity in the area of software upgrading and implementation.

The long-awaited motor/generator set (to regulate the power supply to the computer system) was finally installed in April. This eliminates most of the short-term voltage fluctuations that had been causing system outages during its first 18 months of service. The improvement in "mean time between outages" and "% availability" during the summer is reflected in the following summary:

	Before M/G	After M/G
Mean time between computer outages	7 hr 20 min	13 hr
% availability	89%	92%

In May, demand terminal communications at the Institute were considerably improved with the installation of a Gandalf MINI-PACX port selector in the computer room and the replacement of several dial-up lines by dedicated building circuits to which local terminals are connected via Gandalf line drivers. In September, four, 300 bytes per second (bps) ports were replaced by 1200 bps ports, to provide faster communications for the many new CRT terminals that have been installed. At year's end there were 12 hard-wired terminals and 4 dial-up lines contending for 10 ports (4 at 1200 bps, 6 at 300 bps).

Due to low utilization, the Vancouver remote batch terminal was discontinued in August and the high-speed, dial-up port was terminated in September. Batch output for Vancouver users (Fisheries Management) is now being provided by a delivery service.

Operating system software, processors, and utility routines were upgraded throughout the year. New versions of ASCII Fortran, PL/1, ASCII Cobol, System 2000 (data-base management package), the Text Editor, Sort/Merge, etc. were implemented. New utilities for dumping files/tapes, break-pointing print files, and obtaining master file directing information were among several introduced during the year.

Several applications software packages were acquired late in the year to augment the computing system's offerings. These are:

- the IMSL (International Mathematical and Statistical Libraries) sub-routine library, to provide state-of-the-art mathematical and statistical routines;
- SPARSPAK (A Sparse Matrix Package), primarily for solving large systems of linear equations featuring a sparse matrix structure.
- FESTA (Fast and Easy System for Time-Series Analysis).

A Computing Services Information Bulletin was produced and distributed (in February and October) to users for the purpose of publishing timely information concerning the Univac system. At year's end, an Introductory Users' Guide, and a Users' Manual were nearing completion. These will supplement the Univac manuals and System News files, and will help fill a void in readable user documentation.

In the applications area, the Hydrographic Charts Inventory and Accounts Receivable System was converted from the Vancouver IBM Datacentre to the Institute's Univac 1106. Also, development of the computerized Library Book Catalogue continued during the summer, and some catalogue data were entered into the data-base. These projects were carried out by summer students working under the supervision of Computing Services Staff.

The workload on the Univac system continued to increase, with major users being Offshore Oceanography, Coastal Zone Oceanography, Contract Support Services and Numerical Modelling. The Pacific Geoscience Centre of E.M.R. also became a user in the fall. The value of average monthly usage during 1978 was:

OAS users	\$32,439
Other users	<u>5,706</u>
Total (all users)	\$38,145

This represents a 60% increase over 1977 levels.

Automated Cartography

During 1978, work continued on the development of computerized tools to assist Chart Construction. Four software packages were transferred from the Cyber 74 computer at the Ottawa office of the Canadian Hydrographic Service to the Institute's Univac 1106. These were the Full Graduated Border program, the Small Craft Border program, the Hyperbolic Lattice program and the Curve Fit program. These, combined with a utility program which converts Gerber plot format to Kongsberg plot format, gives this region the capability to produce its own borders and lattices.

Late in March, the Institute took delivery of the hardware required for a GOMADS interactive editing and digitizing system. The equipment includes a PDP11/34 mini-computer with 64K words of memory and hardware floating point, dual RK06 disc drives with 14M bytes capacity each, two 9-track magnetic tape drives, a Talos 36x48 inch digitizing table, and a Tektronix 4014 graphics terminal. The system runs under RSX-11M, a multi-user, multi-tasking real time operating system. The GOMADS interactive graphics editing program was transferred from the CHS in Ottawa and is now operational. It has been used in the production of the compartment chart borders for Fraser River charts 3488 and 3489, as well as for a preliminary version of field sheet 1219. The MOSAIC program was also transferred from the Cyber 74 computer in Ottawa to the PDP11 and is now fully operational. It was used in the production of preliminary field sheet 1219 to convert the projection from UTM to Mercator, to change the scale, and to perform roundings of the soundings.

The Kongsberg flatbed plotter was used by four groups this year. Field Hydrography used it for producing field sheets, using liquid ink on mylar. Chart Construction produced compartment chart borders and a small craft border on photographic film using the light head. Tides and Currents produced a large number of report-quality plots on photographic film using an HP2100 mini-computer system to produce the magtapes. The Geological Survey section of EMR used several paper plots of Loran-C lattices. The Kongsberg plotter is proving to be a reliable and versatile plotting system.

Mini-Computer and Micro-Processor Developments

The various mini-computer systems throughout the Institute are heavily used in applications suited to their versatility, portability and ability to interface with special equipment. Much of the activity involves equipment and programs which have been in use for some time. Some of the new activities are purely programming efforts; some involve exploiting newly acquired equipment.

Hardware acquisitions include a dual-plotter disk for Tides and Currents' HP2100S system, an HP2645 CRT terminal with cartridge drives for Computing, an HP 2648 graphics terminal with cartridge for Coastal Zone Oceanography's HP2112 system, and an HP2635 printing terminal for Offshore Oceanography's HP2100 shipboard computer. The RTE-II and RTE/M Real-Time operating system software was also purchased, although implementation is only in the early stages.

Significant developments include:

- A complex real-time acquisition system for Coastal Zone's acoustic current metre. The graphics terminal is used to display the current profile as the probe is lowered.
- A similar type of system with no graphics, but more printed output was completed for Offshore Oceanography's use on the HP2100.
- The development of drivers for the HP2645 and 2648 terminals has cut down drastically on the need for paper tape in developing software for non-disk systems.
- An HP-user-contributed cross-assembler for the Intel 8080 family of micro-processors was acquired and extensively re-coded, providing a convenient facility for micro-program development.

The past year saw the completion of two micro-processor-based data recording systems. Ocean Mixing's SCRIBE is a dual-processor system combining high speed and low power consumption. A spin-off of the above effort was Remote Sensing's SPECTRE, a compact system which is used for airborne water colour studies. Both these developments made extensive use of the Hewlett-Packard based Editor and Cross-Assembler. If, as planned, a programmer for erasable programmable read only memories (EPROMS) is developed for one of the minis, we may expect the use of micro-processors in special-purpose instruments to become increasingly common.

ENGINEERING SERVICES

J.V. Watt - Head

INSTITUTE ELECTRONICS

**R.A. Cooke	*C. Hollinger
T.A. Curran - Project Engineer	B.A. Johnson
*C. De Jong	R. Loschiavo
L.W. Dorosh	R.A. Muse
J.L. Galloway - Project Engineer	M. Osborne
D.G. Gregson	***T. Soutar
E.W. Hinds	W.R. Taylor - Head, Technical Support

*Joined in 1978

**Transferred to Frozen Sea Research Group during 1978

***Transferred to Ocean Chemistry during 1978.

Institute Electronics provides electronics engineering and technical support for survey, research and ship operations in the Pacific Region. Both the Engineering Support Group and the Technical Support Group experienced a very active and successful year during 1978.

Engineering Support Group

The support to the Institute during the past year involved a considerable variety of design, prototype manufacture, testing and consulting activities. Some of the more prominent of these tasks were the completion of two micro-processor-based data acquisition systems, extensive design modifications to a current shear probe, a special purpose winch controller and an extendible echo sounder transducer on the M.V. *Pandora II*. The data acquisition systems SCRIBE (Ocean Mixing Section) and SPECTRE (Remote Sensing Section), provide the capability to record onto 9 track tape small scale ocean turbulence data aboard the *Pisces IV* and spectrometer data aboard small aircraft respectively.

Considerable engineering effort was expended in modifying a current shear probe developed by the Institute's Offshore Oceanography Section and in managing the assembly of a second such system (Coastal Zone Oceanography Section). The modification involved tasks such as the upgrading of the probe-to-surface communications link, the addition of a height-above-bottom measurement capability, improved processing software and recalibration of the sonic head. A "YO-YO" winch controller (Coastal Zone Oceanography Section) was also developed to facilitate shear probe operations.

The extendible transducer installation (Hydrography) aboard *Pandora II* was undertaken as a result of severe aeration problems which hampered survey operations. A study of the problem was conducted and a system utilizing a hydraulic ram to provide a two metre extension of the transducer was fitted in one of the ship's forward tanks.

Other tasks involved a Fluorometry data acquisition system (Ocean Ecology), PHAS consultations (Portugese Hydrographic Service), monitoring contracts (Hydrography) and continued consulting support to the various divisions of the Institute.

Technical Support Group

During 1978 the Technical Support Group provided installations, equipment preparation and field maintenance support in varying measure to the Western Arctic Survey (M.V. *Pandora II*), the West Coast Survey (C.S.S. *Parizeau*), the MacKenzie-Athabaskan Survey (M.V. *Radium Express*), the 1978-79 FGGE Tropical Experiment (C.S.S. *Parizeau*), numerous small coastal surveys (C.S.S. *Richardson*) and to major shore parties both in Vancouver and Silva Bay.

New field equipment added to the maintenance and installation inventory during 1978 included a Canadian Marconi Satellite Navigation System, two additional portable hydrographic acquisition systems (PHAS), a Motorola communications and paging system and a number of Loran-C and marine VHF receivers. Late in 1978, a Raytheon correlation echo sounder processor, CESP III, was received and will undergo field tests in early 1979.

The Institute radio base station installation XMH-59 was completed and with the exception of the antenna remote control capability, it is fully operational. To date the system has proven effective in providing excellent communications with department vessels from the Western Arctic to the equatorial Pacific. Among other projects and modifications the Group interfaced the Motorola paging system to PHAS which provided the data acquisition system the capability of paging an absentee watchkeeper.

MECHANICAL ENGINEERING

G.R. Smith - Project Engineer

A.E. Moody

J. Steeples - Head, Mechanical Support

In addition to Industrial Liaison activities, Mr. Smith has been providing general supervision of the Mechanical shops and mechanical engineering services. Mechanical engineering has been provided previously on a consulting basis, but the addition of an Engineering technician/draftsman, Mr. Redman, whose time is shared with Ships Division, will make it possible to handle routine design work efficiently. Typical requests in the past year were a tripod structure for supporting instrumentation under the hull of the Pandora II, provision of advice on *Pisces IV* equipment and the design of a retractable transducer ram for the *Pandora II*.

The Mechanical Support Group has been providing a high level of support to the users of the Institute Shops by way of assistance and advice. In addition to a major consolidation of shop facilities in mid-year, numerous projects were undertaken and completed. Projects included the construction of an under hull tripod (Institute Electronics), design and construction of an accelerometer calibration jig (Ocean Mixing), a zooplankton sorting device (Ocean Ecology), miniature pressure cases (Ocean Mixing), straightening of the Institute radio antenna mast (Institute Electronics) and the design and manufacture of special purpose connectors, elbows, plates, mounts, front panels, pulleys and such items for all sections of the Institute.

INDUSTRIAL LIAISON AND CONTRACT ACTIVITY

G.R. Smith - Industrial Liaison Officer

As a result of funding restrictions, it was predicted that considerable effort would be required to maintain the level of contract activity reached in 1977/78. In the past year, contracting has increased by approximately 20% and total expenditures for the year will exceed 2 million dollars. This increase was primarily due to bridge funding from the Department of Supply and Services, which enabled us to conduct a number of major projects. The most notable were a chemical baseline study, the development of a miniprocessor-based acoustic tracking system and improvements to the safety and operating capability of the *Pisces IV*. Results from these projects have been excellent and have generated interest from prospective customers in the private sector.

An interesting and perhaps significant change has taken place in 1978. There are now several new programs through which research and development can be undertaken by industry or through which contracted activities can be supported. Also the importance of non-government markets for products and services developing from contracts is being recognized. New support funding is not being made available directly to government departments but to companies willing to take the initiative in proposing useful projects. By involving contractors in the process of generating contract activity, transfer of technology should become more meaningful and an increased research and development effort by the private sector should result. With some encouragement, the companies involved in marine sciences have responded to this challenge and there are good examples of sound scientific initiative emanating from the private sector.

OCEANOGRAPHIC DIVISIONS

P.W. Nasmyth - Regional Oceanographer

S. McKenzie - Secretary

Final consolidation of all oceanographic activities in the new facilities at Patricia Bay was completed early in 1978 and we have now experienced our first full year (almost) of operation as an "institute". The results are gratifying in terms of productive interaction between groups within the oceanographic divisions and between Oceanography and Hydrography. Plans are maturing for extensive cooperative and interdisciplinary programs to be undertaken over the next few years. Our hope is that this sort of cooperation will lead to economies of operation as well as enhanced scientific output.

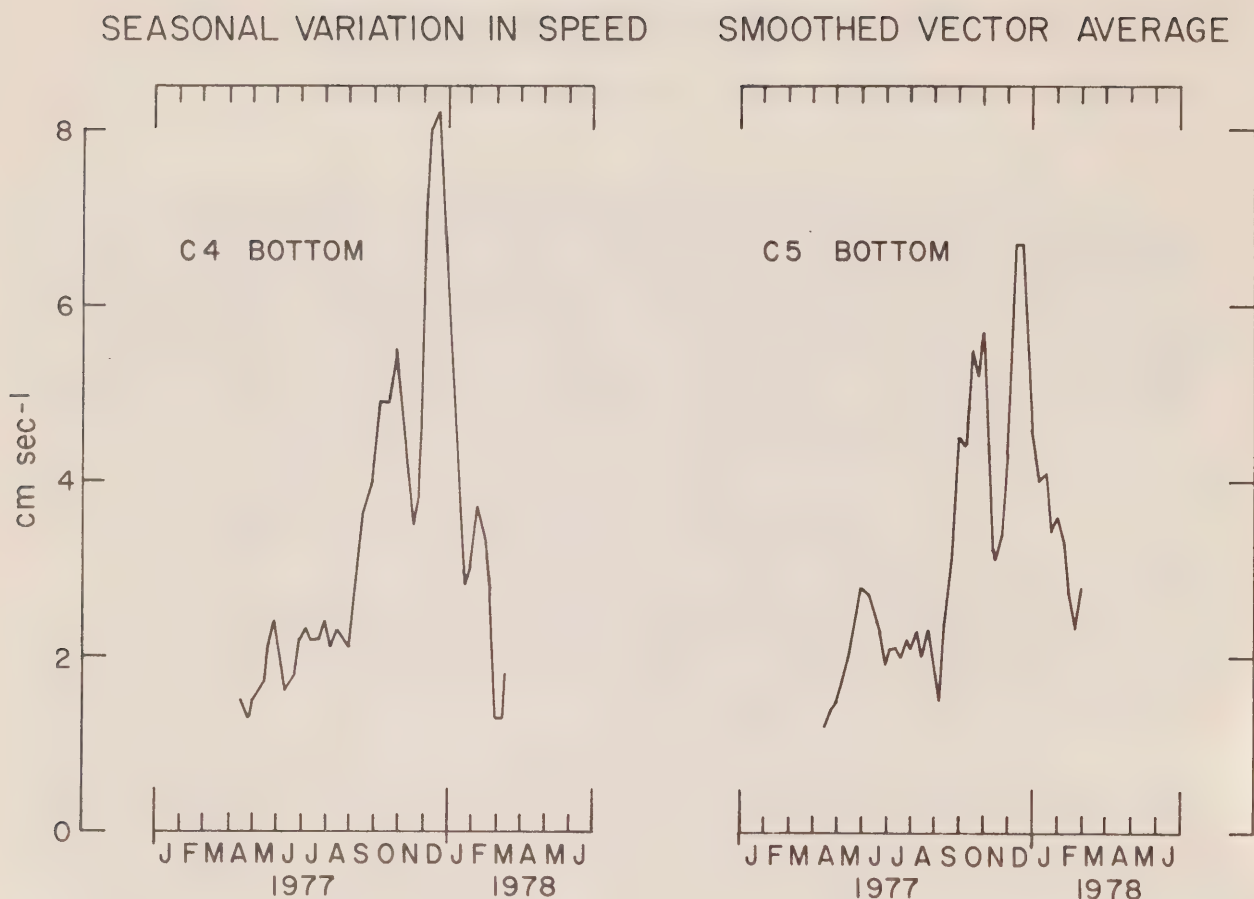
A general shortage of operating funds has resulted in some restriction in activities but has not yet had any serious impact on program. It may even have had some beneficial side effects by further encouraging economies through mutual support between groups and sharing of equipment and facilities. A negative result, if present trends continue, will be a reduction in funds available for contracting and a deterioration of the Institute's Make or Buy position.

In the continuous evolution of programs to meet present and anticipated demands for knowledge, certain trends have been felt this year. There will be a shift in emphasis from the inshore coastal waters of British Columbia to the Continental Shelf. While much remains to be done inshore, we have reached the stage of at least a preliminary understanding of the significant features of some of the more critical areas - whereas almost nothing is known of the oceanographic characteristics of the Continental Shelf or the mechanisms of offshore influence on coastal waters. Again this year our Arctic program has been heavily supported by non-OAS funds. There are indications that this outside support may be drying up, and if this trend continues, the result must be an overall cut back in Arctic activity together with more careful selection of programs on the basis of priority requirements.

Three aspects of the oceanographic program have, in particular, this year attracted wide interest in the world oceanographic community:

- i) the CO₂ balance between ocean and atmosphere,
- ii) the dynamics of fjord systems, and
- iii) the "drifting buoy" component of the First GARP Global Experiment.

All are treated in some detail in the reports of the separate sections which follow.



Observations of water movement near the bottom of Crozier Strait showing the weekly average current as a function of time. Surface and mid-water current meters which were suspended from the ice had to be removed in June 1977 to prevent their destruction by the ice. The records thus indicate (but do not prove) that there is a major increase in southward transport through the Strait in mid-winter.

OCEAN PHYSICS DIVISION

P.W. Nasmyth - Chief of Division

FROZEN SEA RESEARCH GROUP

E.L. Lewis - Head

R.A. Cooke	D.R. Richards
P.E. Greisman* Postdoctoral Fellow	R.B. Sudar
A.W. Koppel	D.R. Topham
R.A. Lake	E.R. Walker*
J.M. McNeill	A. Wharton** Computing Services
S.W. Moorhouse	M.E. Woodward* Computing Services
R.G. Perkin	

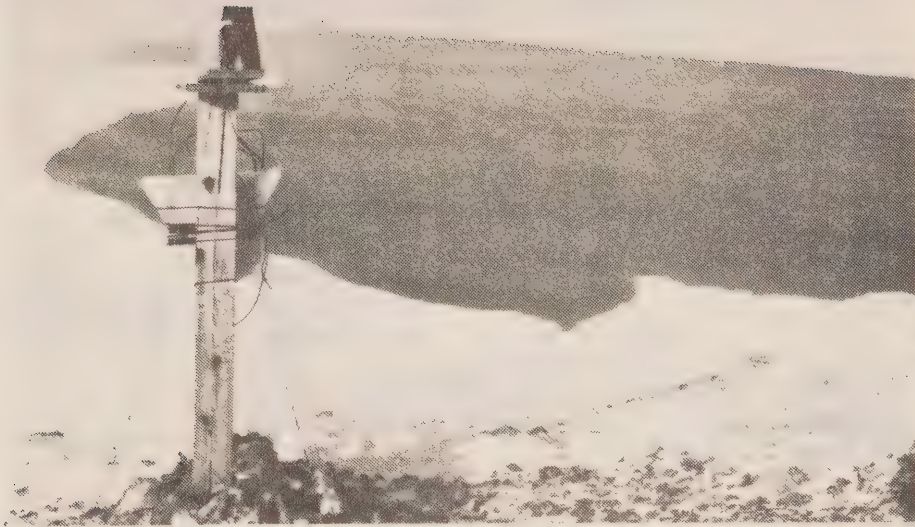
* Left in 1978

** Joined in 1978

During 1978 the Frozen Sea Research Group made field trips concerned with the measurement of currents in channels of the Canadian Arctic Archipelago, the oceanography of Bridport Inlet on the southern shore of Melville Island, and a preliminary investigation of the problems of taking measurements within polynyas (areas of open water within growing sea ice). Additional work has been done on instrument development, the physics of underwater oilwell blowouts, pollution in an arctic fjord, and the "Practical Salinity Scale (1978)" - a redefinition of salinity for seawater.

Current meters were recovered from Crozier Strait between Cornwallis and Bathurst Islands and the tracked vehicle train moved around the northern tip of the former island to deploy current meter chains in Wellington Channel. The CTD system in the oceanographic slédge has been interfaced with an HP 9825A minicomputer to provide a real time salinity and temperature readout. The data from Crozier Strait has been analyzed showing that currents were mainly tidal but suggesting that the residual southerly transport has a maximum around mid-winter, there being almost an order of magnitude difference between average summer and winter current speeds recorded at two current meters near the bottom. A major effort involved the deployment of sonically oriented current meter arrays in Wellington Channel, providing a direction reference independent of the earth's magnetic field and thus suited for use near the magnetic pole. The system was developed for the Institute under contract and work is continuing in the refinement of the design and on the analysis of operational data.

Bridport Inlet on the south coast of Melville Island is the proposed site of a PetroCan liquid natural gas (LNG) plant which would supply LNG carriers plying on a year-round basis between Bridport Inlet and markets on the east coast of Canada. The oceanography of the Inlet is important and has resulted in at least a two year study. One member of the group acted as an expert advisor, accompanying a contractor working for PetroCan in the Inlet in February 1978. Three members of the group collected data in the Inlet during late August when recording instruments were deployed for recovery in 1979, when further work will be done.



The polynya off the north of Dundas Island in April 1978. The picture is taken from the tip of Cape Collins 105 metres above sea level and shows the time lapse camera set up in the foreground. The polynya is of dimensions about 1.6 x 0.8 kilometres.



Operation of inflatable boats in the polynya in April. The men are wearing plastic foam exposure suits as a protection against accidental immersion in the water.

The polynya existing off Cape Collins on Dundas Island (76°08'N, 95°00'W) was investigated to define problems in logistics and equipment design encountered in operating on the polynya and the surrounding ice sheet at air temperatures ranging to -30°C. This was the first year of a proposed three year program of cooperative studies of air/sea energy exchange being conducted with the Bedford Institute of Oceanography and the Atmospheric Environment Service, Downsview, Ontario. The latter department successfully operated one of their instrument towers close to the base camp.

The design of a new salinity cell suitable for use on a chain has been published and the first such chain deployed. Investigation of the long-term stabilities continues. A major effort has gone into the development of electronic packages for model aircraft to be used to investigate temperature fields above polynyas. Work is progressing on the data package designed to telemeter temperature and pressure information and, using a photosensor, to allow the ice/water edge to be detected when traversed by the aircraft. A system enabling the position of the aircraft to be determined utilizing a Decca mini fix system should be available by the spring of 1980.

Further work has been done on data acquired during the simulated shallow oilwell blowout conducted in 1976, with a view to obtaining a more accurate understanding of the bubble plume. Work under contract has continued at the Department of Chemical Engineering, University of Calgary to investigate such phenomena as hydrate formation which will occur during a deep oilwell blowout. Hydrate formation, a theoretical possibility under the pressures and temperatures to be expected in arctic waters below about 150 metres were shown to occur by a gas release from the submersible *Pisces IV* in Jervis Inlet, B.C. These results have now been duplicated in the vertical high pressure water tunnel which has been built in Calgary. Problems of supersaturation of gas in oil drops during ascent to the sea surface are also being studied and it is hoped that a complete picture of deep oilwell blowout dynamics will be available early in 1979 to enable a proper scenario to be written. A study of the natural disposition of oil and gas arriving at an ice/water interface has shown that oil will lie below the gas bubble unless in sufficient quantity to spill over and upwards onto the surrounding ice.

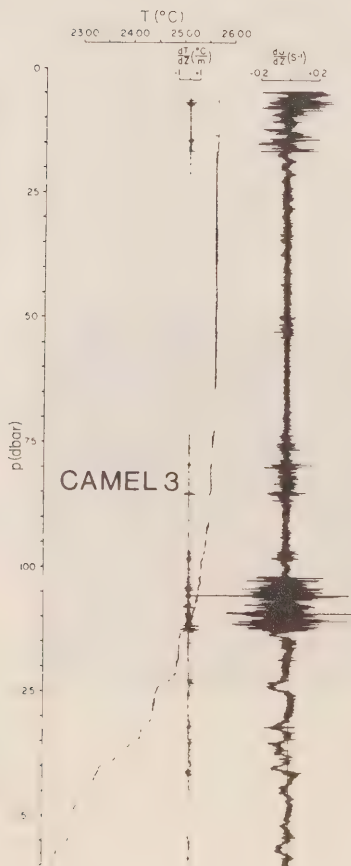
Studies made of pollution in a fjord on the west Greenland coast resulting from mining operations at Mârmorilik demonstrated the effect of the rejection of salt by sea ice during growth on vertical winter circulation and pollutant movement. We have deployed recording instruments in this fjord in conjunction with the Danish Geological Survey program.

The group has been very active in studies leading to the new "Practical Salinity Scale (1978)" due to be promulgated shortly in order to standardize salinity observations taken throughout the world.



Frozen Sea Research Group recovers surface units from the sea ice of Wellington Channel. Note the telemetering antenna on the left of the picture. Data acquired by current meters is transmitted sonically to the surface and hence by radio telemetry to a recorder on a local hilltop.

* * * * *



By measuring turbulent velocities in the ocean surface mixed layer, we hope to contribute to an understanding of the dynamical processes which link the atmosphere and the oceans. This profile of small-scale shear (dU/dz) was taken through a surface mixed layer in the Sargasso Sea, using the Osborn profiler CAMEL. At a time of active wind forcing, turbulence driven directly from the surface appears to be confined to the upper 15 dbar of the water column, while mixed layer deepening may be associated with the patch of strong shear at the mixed layer base around 110 dbar.

OCEAN MIXING SECTION

P.W. Nasmyth - Head

G.G. Chase
A.E. Gargett

R.C. Teichrob

This year analysis of data from the towed system was completed, with publication of results from an investigation of the relationship between finestructure and microstructure in the frontal region between coastal and offshore water masses along Line P. Ocean Mixing may undertake further investigation of ocean frontal activity as part of a cooperative experiment with other Canadian and U.S. agencies in 1980 to study the subtropical front in the North Pacific. This would also be a first venture offshore with *Pisces IV*.

A study of turbulent dissipation levels in the surface mixed layer, as observed during two occupations of a site in the middle of the Sargasso Sea during the 1975 cooperative Fine and Microstructure Experiment, has been completed and will appear in the Journal of Physical Oceanography. A data report on the complete results obtained during this experiment will shortly appear as an Institute of Oceanography, University of British Columbia Manuscript Report (with T. Osborn). A journal paper is also being prepared. Experience gained with analysis of this data from the Osborn-Siddon "shear probe" has proved valuable, and we now incorporate the use of similar probes as part of the *Pisces* system.

The modified sensor system for *Pisces IV* proved largely successful in trials in early 1978, with two significant exceptions. Electronic interference from the acoustic current meter picked up in other components of the system proved to be very persistent and of such magnitude that some signals were of little value. Secondly, the new data acquisition system based on Emerson digital cassette units was not sufficiently far advanced for a realistic trial. The acoustic current meters were replaced with a three-dimensional array of small propeller-type meters developed at the University of Washington.

Further trials in November with an almost completed data acquisition system were completely successful and good data were obtained in two situations; (a) in the mixing region in the outflow of the Fraser River in the southern Strait of Georgia, and (b) in mixing zones and through unstable internal waves generated by tidal flow over the sill in Knight Inlet. The latter was done in conjunction with the measurements taken from the surface by Coastal Zone Oceanography and should lead to an estimate of the amount of tidal energy lost to turbulence in flow over the sill. With measurement of all three components of velocity with a spatial resolution of 2 - 3 cm or better it should be possible for the first time to get a quantitative indication of the isotropy of the dissipation scales of the turbulent field. Analysis of the data is in progress.

COASTAL ZONE OCEANOGRAPHY

D.M. Farmer - Head

W.H. Bell
R.H. Bigham
H.J. Freeland
L. Giovando
G. Kamitakahara

A.P. Lee
J.H. Meikle
D.G. Sieberg
L.A. Spearing
J.A. Stickland
D.J. Stucchi

This year Coastal Zone greatly extended its earlier program to study the dynamics of tidal interaction with sills and its influence on circulation. Analysis of data has led to new theoretical approaches applicable to deep estuary flows and a laboratory model has been used to simulate some of the processes thought to occur in nature.

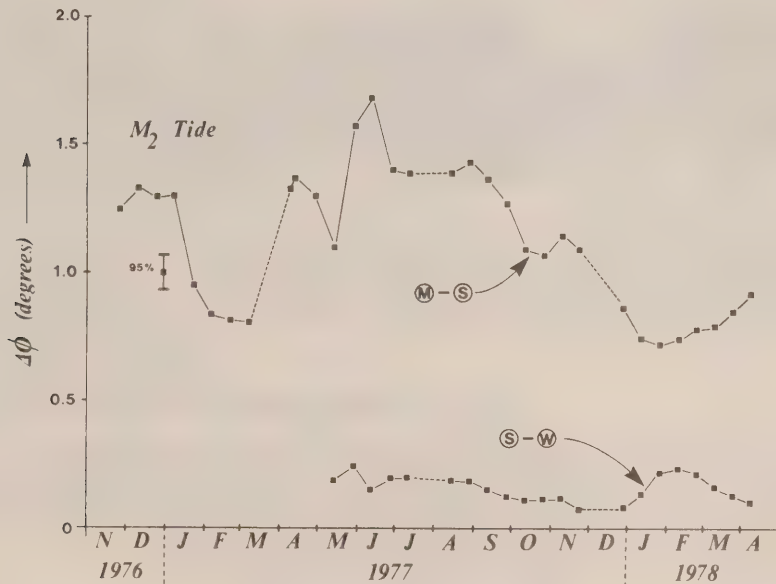
Ongoing work includes the detailed analysis of tidal exchange between the Quatsino and Rupert-Holberg inlet system, the further development of a mooring model and maintenance of the daily salinity/temperature sampling program from B.C. light stations. The integration of a profiling current meter/CTD with real time shipboard display of data has proved a valuable addition to our experimental capability. Oceanographic projects managed by Coastal Zone included the concluding phase of the study of circulation in the channels leading to Kitimat as well as two studies of Alberni Inlet related to the ocean dumping problem.

Dynamics of Flow over Sills

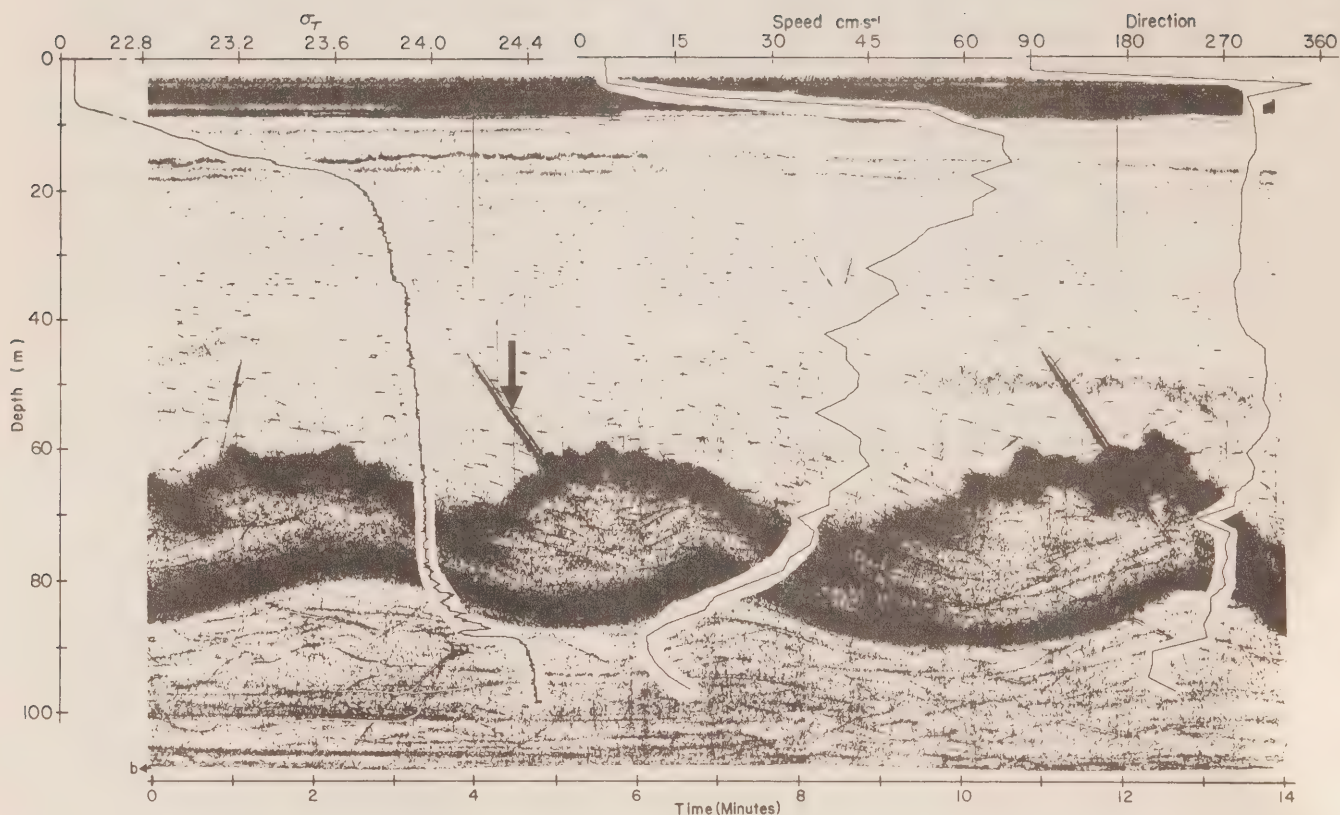
In this second year of studying the circulation in Knight Inlet, we have continued to take salinity-temperature profiles at monthly intervals, have made a precise and detailed tidal survey of the inlet and used a current-meter mooring to study the structure of the internal tide. In July we were again joined by Professor J. Smith with the University of Washington vessel *Onar*. In an intense three-week cruise we used fixed depth and profiling CTD/current meters, together with acoustic techniques, to explore the detailed structure of tidal interaction with the sill, the dynamics of which had only started to become apparent at the very end of the previous joint cruise in 1977.

These more detailed observations revealed a remarkable variety of phenomena. Early measurements with the two vessels confirmed that, at least near the sill, the flow was essentially two-dimensional. Phenomena that could be interpreted as hydraulic jumps were observed, but in contrast to our expectations, summer measurements showed that the structures behaved like mode 2 waves, with the streamlines splitting just upstream of the sill crest. We also observed mode 2 lee waves and, much later in the year when the stratification was weaker, mode 1 lee waves. Separation on the bottom boundary layer was also tracked, both with current-meter profiles and acoustically, and the separation point appears to be closely linked to the shape and position of the lee waves.

The longer term measurements of tidal height and density structure have provided the basis for development of a two-layer circulation model. This theoretical model has been used to examine the divergence of potential energy flux in Knight Inlet and provides a basis for interpreting observations of tidal energy loss and resultant mixing near the sill. The fraction of tidal energy available for mixing is sensitively dependent upon the stratification and can be observed through small changes in the phase angle of the tide across the sill. Current meter observations, in turn, have shown how tidal mixing influences the estuarine circulation. A significant fortnightly (MS_f) component of flow occurs in the currents, but has no corresponding signal in the tidal height observations. This result is consistent with the concept of stronger estuarine circulation associated with the stronger tidal mixing occurring during spring tides.

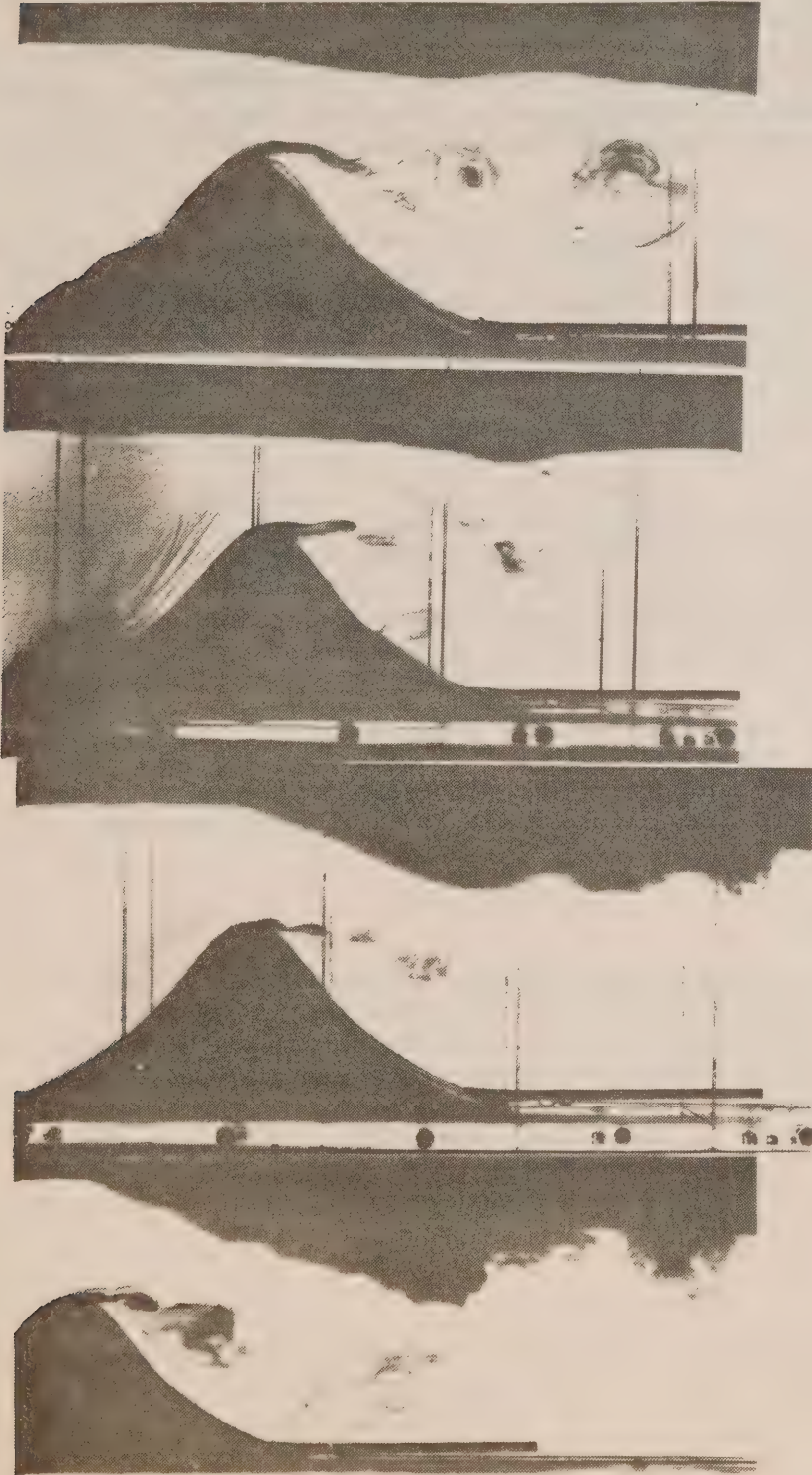


The M_2 tidal component in Knight Inlet shows a large change in phase between two stations, labelled M and S in the figure above, and a small change between S and W. In fact stations M and S are closer to each other than the stations S and W. Furthermore, the phase difference between M and S shows a large seasonal variability. We attribute the large lag to internal wave generations, and similar processes, by the tidal flow over the sill in the inlet; a process that extracts energy, locally, from the barotropic tide. Since the stratification is seasonally dependent, the energy that can be put into internal motions is also seasonally dependent.



This figure shows profiles of water density (left hand curve), current speed (center) and direction (right), superimposed on an acoustically derived image of flow near a sill in Knight Inlet. The wave-like feature in the lower part of the figure is associated with a free shear layer separating the swiftly moving water above from the nearly motionless water beneath. Sloping line (arrowed), shows path of profiling instrument.

A simple laboratory model in which a small obstacle is towed back and forth in a tank of stratified water has been used to study some of the processes that might be occurring in nature. A striking aspect of these studies has been the observation of the way in which boundary layer separation can be suppressed under certain conditions of stratification and the significance of boundary layer separation to the overall response.



Two-layer flow over a steeply sloped obstacle is modelled in this tank experiment, used to explore effects of tidal interaction with sills in coastal waters. Four separate runs, at progressively higher speeds, show the transition from relatively weak lee waves to more violent phenomena similar to those observed in Knight Inlet. The upper, dark layer is fresh water, the clear fluid is salt water; dye crystals placed to the left, just ahead of the sill, trace the path of vortices shed from the sill crest.

The Tidal Jet in Rupert-Holberg Inlet

Observations of the tidal jet issuing from Quatsino Narrows into Rupert-Holberg Inlet reveal that there are two types of discharge; a buoyant surface jet characterized by strong surface currents, and a negatively buoyant flow characterized by strong bottom currents. Observations of the buoyant jet have been compared with the results predicted by existing models of heated surface discharges in which the behaviour of the discharge is determined by the initial densimetric Froude number of the flow. Based on this parameter, the agreement between the predicted and observed vertical penetration of the jet is good.

Precipitation, through its influence on the density of the surface, appears to be the dominant factor controlling the type of discharge, although upwelling and tidal amplitude may also play an important role. The rapid and frequent exchange of the deep basin waters resulting from the intense tidal mixing of the jet gives this inlet a character atypical of shallow silled fjords. (D.J. Stucchi).

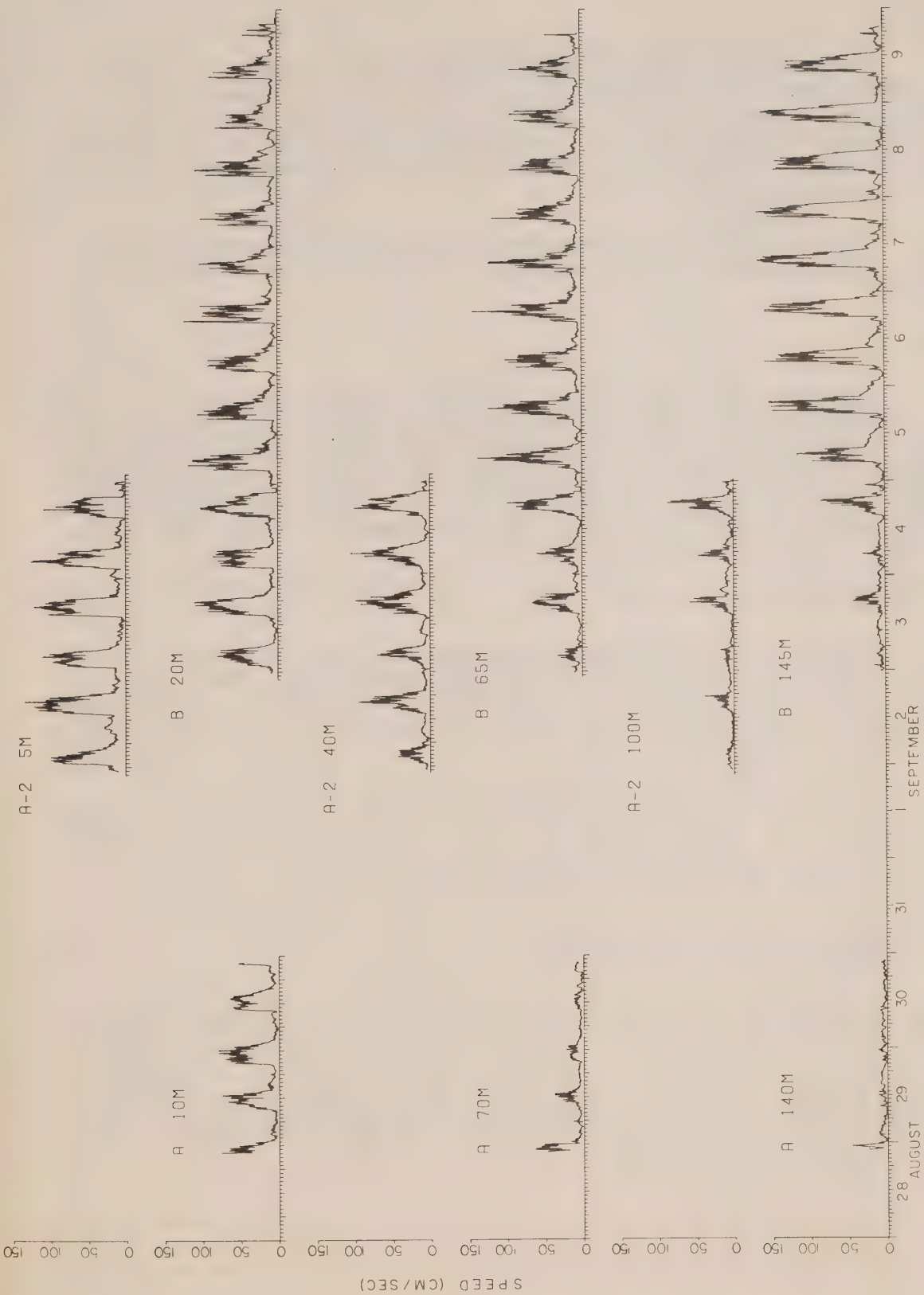
Mooring Techniques

Investigation into mooring problems was continued with an examination of strumming problems and of the influence of turbulence on drag. Development of a 3-dimensional static mooring model was begun, as an aid in examining oceanographic data obtained from sub-surface-moored instruments. Assistance with mooring problems was provided to other groups in the Institute.

We acquired and tested the new Neil Brown Acoustic Current Meter. Unfortunately an electronic fault prevented a full data recovery, but initial results look hopeful and translation and data processing software have been developed. Further tests will provide the basis for evaluation of this instrument. (W.H. Bell).

Instrumentation Development

A significant development, in co-operation with other groups in the Institute, was the integration of a profiling CTD-current meter with real-time shipboard data processing. Plots of current speed and direction and of salinity (or density) generated as the data are acquired, enormously improved our ability to interpret results in the field during the study of rapidly changing processes such as tidal flow over sills.



Current speed data taken on the axis of the tidal jet in Rupert-Holberg Inlet showing the initial period of buoyant flow followed by a transition to strong bottom currents (negatively buoyant flow).

Ocean Dumping

The watching brief on developments in ocean dumping technology was continued, with the production of a further review of papers relating to the physics of dumped material disposal. Two contracts relating to dumping in Alberni Inlet were let, one dealing with a model of the internal tide and the other with the variability of coastal upwelling and the consequences of flushing of the inlet.

Plans were laid for a new program of research in Alberni Inlet which will examine the exchange of water in the deep basins in some detail. (W.H. Bell).

Kitimat Study

This year the observations undertaken as part of a study of circulation in the complex of channels leading up to Kitimat were concluded and write-up of the results is near completion. This work is being conducted under contract and was motivated by concern over possible port developments at Kitimat. The project has included an analysis of the estuarine and wind-driven response and also of the tidal circulation. Final reports of this study will be available in early 1979.

Saanich Inlet Deep Water Renewal

Several moored instruments were placed on and inside the sill of Saanich Inlet from August to November of 1978. Preliminary examination of these data reveal that at least 3 events of deep water renewal occurred during the period. The denser renewal water is observed at the sill for periods of 5 to 7 days, coincident with times of large tidal ranges. Although the renewal water is of limited vertical extent (10 m or less) its inflow velocities are relatively large (60 cm/sec maximum). Future work will be directed towards the identification of the source of the renewal water, and the determination of the importance of those events to the exchange of the deep basin waters. (D.J. Stucchi, L.F. Giovando).

Continental Shelf/Alberni Inlet Project

Plans were laid and preparations made for a study of upwelling and other phenomena on the continental shelf off Vancouver Island, starting in January 1979. Simultaneously a study of deep water exchange, which is thought to be associated with the upwelling, will be carried out in Alberni Inlet. The project will involve extensive current-meter and CTD observations and will be integrated with other programs in the same area being carried out by other groups in the Institute.

OFFSHORE OCEANOGRAPHY SECTION

J.F. Garrett - Head

C. de Jong	J. Love
P.M. Kimber	B.G. Minkley
L. Kuwahara	M. Miyake
J. Linguanti	S. Tabata
*P.R. Lacroix-Computing Services	R.E. Thomson

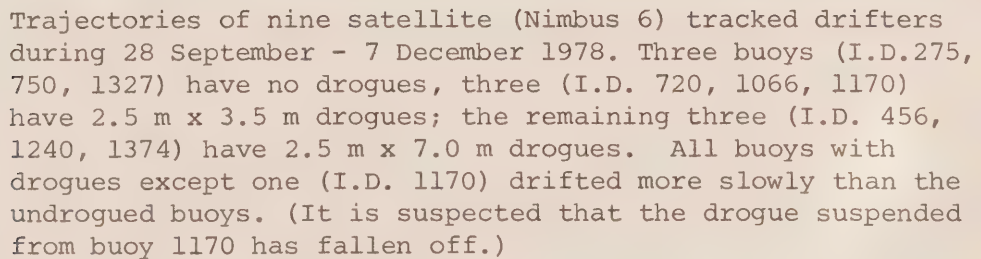
*Joined in September 1977

The main efforts of the Offshore Oceanography Section this year have been directed towards continuing observations and examination of data taken at Station P, Line P and other areas of the eastern North Pacific Ocean; obtaining data in coastal seaways, notably in Johnstone Strait and southern Strait of Georgia-Juan de Fuca Strait; examining drifting buoy trajectories in the open ocean and testing recently developed instruments - the current shear probe developed at IOS, the commercially-available expendable conductivity-temperature-depth probes (XCTD) and expendable sound velocity-temperature-depth probes (XSVTD).

Dr. J. Garrett is spending approximately one year at the Service Argos/FGGE (First Garp Global Experiment) Buoy Control Centre - Centre National D'Etudes Spatiale in Toulouse, France, where he is managing the international FGGE buoy observing system and data processing associated with it.

Climatology and Large Scale Air-Sea Interaction

The oceanographic time series programs at Ocean Station P and Line P have been continued into their 23rd and 20th year respectively. Due to the rising overall cost of maintaining the program it has been found necessary to reduce the level of effort devoted to make field observations. This has been done by sending an oceanographer on only one instead of the two weatherships. An appreciable amount of time was spent this year editing the data collected up to the end of 1976. Data of dubious quality have been removed from the working weathership data sets. However, all the original data "as observed" will remain in the original data sets. A cursory examination of the Station P data has revealed the occurrence of important climatic changes of water to a depth of at least 500 m. For example, at a depth of 200 m, well below the level of direct seasonal influence of atmospheric forcing, temperature changes of approximately 2°C have occurred within the relatively short period of 1-2 years. In particular, the years 1960 and 1974, were characterized by the presence of water of relatively high temperature whereas 1965 was featured by water of low temperature. The warm waters in 1960 and 1974 were also characterized by lower oxyty (concentration of dissolved oxygen) than normally observed at Station P. (Tabata).



All available STD and bathythermograph temperature data collected along Line P since 1968 are being processed to determine spatial and temporal variations in oceanic "noisiness" levels (mean variances) off the British Columbia coast. Results indicate that the generally rapid decrease in temperature fine-structure away from the continental shelf to more quiescent deep-sea waters is frequently disrupted by the presence of pronounced (2°C) intrusions of cold and warm water. Three dimensional plots of the spatial variability of temperature variance along line P are being prepared. (Thomson).

A SEASAT wave rider buoy and a Roll-and-Pitch buoy were both deployed at Station P during 1978 on behalf of the NOAA agencies.

In order to determine the effect of winds and waves in the Canadian FGGE drifting buoys, nine buoys comprising three without drogues, three with short drogues (2.5 m x 3.5 m) and three with long drogues (2.5 m x 7.0 m) were released at Station P (50°N , 145°W) and their drifts monitored. The drogues are suspended a few metres below the buoys. Based on 66 days of observations, the results showed that the undrogued buoys travelled northeastward at an average speed of 12 km/day while the drogued buoys travelled eastward at less than one-half of the above rate indicating that the undrogued buoys are affected considerably by the winds. (Garrett).

Ocean Response Study

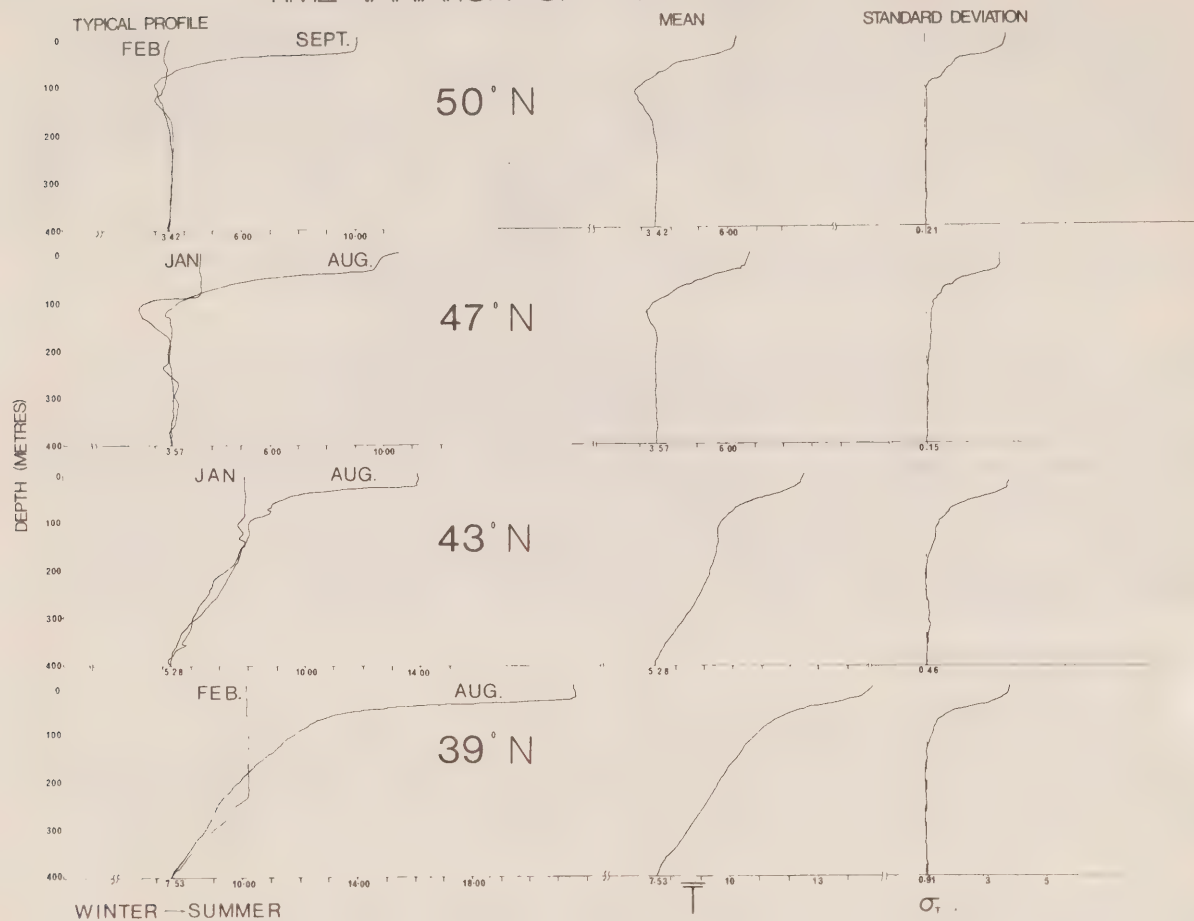
In order to understand the role of the Pacific Ocean in influencing the climate of North America, it is essential to understand the mechanism which produces change in the sea surface temperature. This has been the motivation for the study of upper ocean dynamics of the top 300 metres.

Offshore Oceanography has been participating in international experiments focussing on two areas. MILE (a mixed layer experiment) was staged August-September 1977 with three ships in the vicinity of the Ocean Weather Station (50°N , 145°W). This experiment involved direct measurement of currents, salinity and temperature over a horizontal scale ranging from 150 kilometres to a few hundred metres and on a vertical scale from the surface to 300 metres. The Institute scientists, with the assistance of Canadian Forces Argus aircraft, determined the meso-scale structure and its time evolution. The most important finding indicates that local surface heating accounts for only 60% of the heat exchanged in the upper 100 metres of the ocean, while the remaining 40% is due to advection at various depths and with different time scales. The mechanisms responsible for these findings have been identified.

The other major area of activity involved participation in the NORPAX anomaly dynamics study. An AXBT survey of a North Pacific area with dimensions $15^{\circ}(\text{N-S}) \times 5^{\circ}(\text{E-W})$ continued throughout 1978. Analysis of the data indicates that subsurface advective processes play a major role in establishing stability in the entrainment region of the mixed layer. These results reinforce the findings of the mixed layer experiment.

Latitudinal Variation of Upper Ocean Temperatures

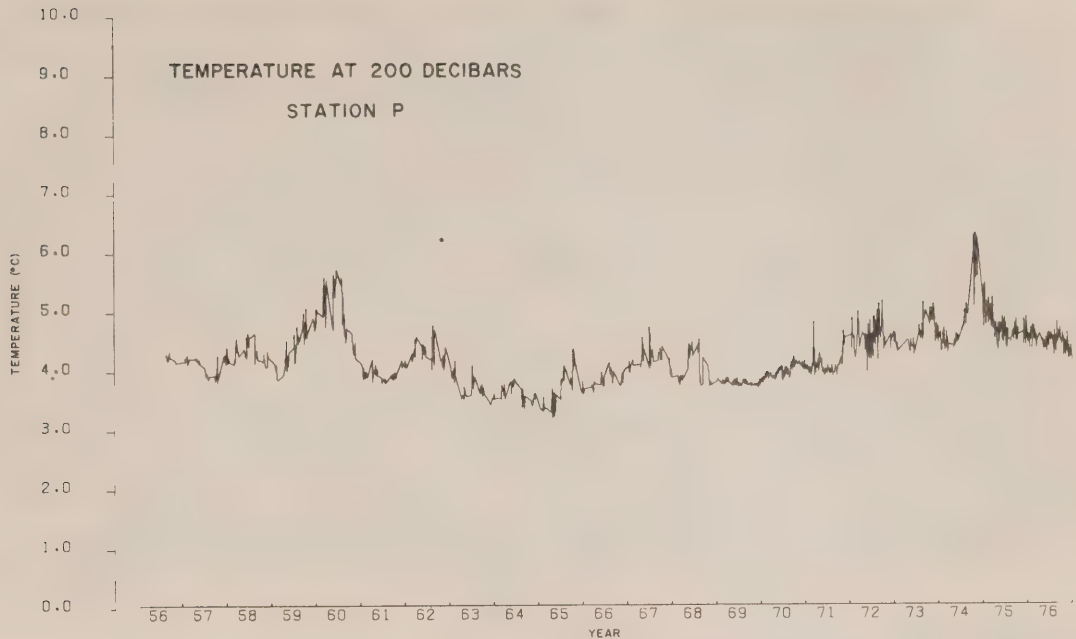
TIME VARIATION OF AXBT TEMPERATURE



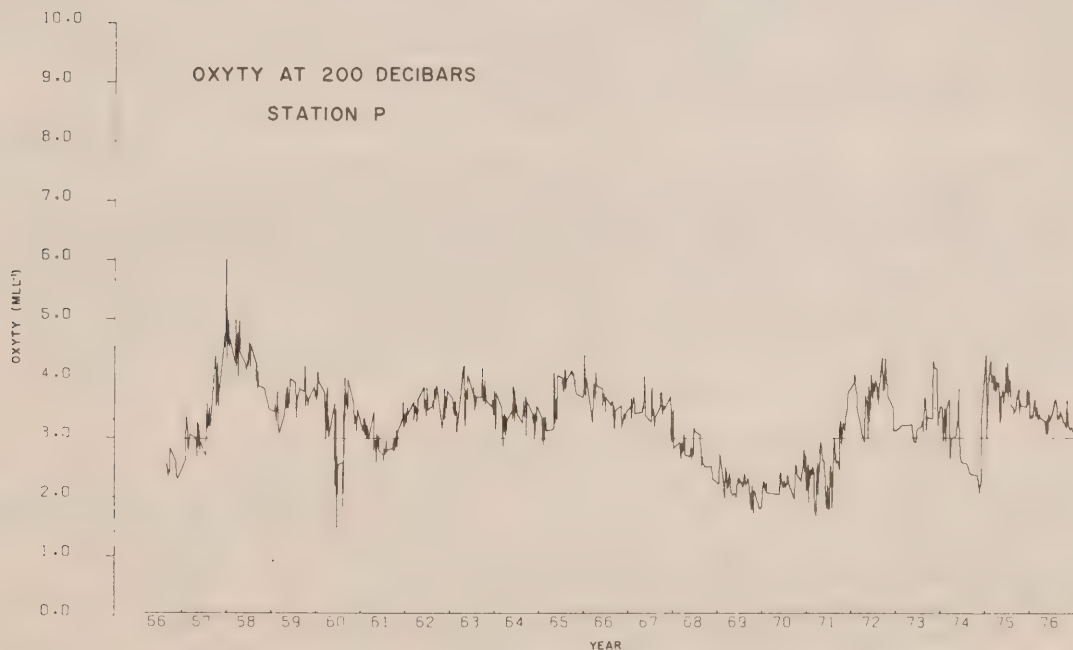
During an AXBT flight every two weeks the latitudinal variation of the temperature structure in upper 400 metres was determined. Analysis of mean temperatures suggests cold water advection below the seasonal thermocline in high latitudes and warm advection below the halocline in low latitudes. The crossover latitude coincides with the sub-arctic frontal zone.

The residence time of these advecting intrusions appears to be of the order of 2 months, with dimensions normally in the order of a few hundred kilometres but in some cases only of the order of few 10's of kilometres. The relative importance of the scale of these inhomogeneities requires further analysis. (Miyake).

Examples of Time-Series Record at Station P, 1956-1976



At depths well below the level of direct seasonal influence of atmospheric forcing (approximately 200 metres) the temperature undergoes relatively large climatic changes, with high temperatures occurring in 1960 and 1974 and low temperatures in 1965. The difference between the maximum and minimum is just over 3°C.



The oxyty also undergoes large climatic changes, varying from a maximum (>5.3 ml/L) reached in 1957-1958 to a minimum (<1.6 ml/L) in 1969-1971.

Variability of water properties in the surface mixed layer

It has been known for some time that the surface mixed layer of the ocean is generally isothermal to within $\pm 0.03^{\circ}\text{C}$. However, in order to determine to what greater degree, if any, the layer is uniform or variable in temperature, salinity and concentration of dissolved oxygen (oxyty), time-series oceanographic data based on hydrographic stations obtained at Ocean Station P (50°N , 145°W) from 1956 through 1976 have been examined. The surface mixed layer is found to be homogeneous in temperature, salinity and oxyty to within the present accuracy of standard measuring techniques. The water within the layer is isothermal to within $\pm 0.02^{\circ}\text{C}$ during the cooling season (October through March) and to within $\pm 0.03^{\circ}\text{C}$ during the heating season (April through September). It is isohaline to within $\pm 0.003^{\circ}/\text{oo}$, and iso-oxygenic to within $\pm 0.05 \text{ ml/L}$, during both seasons. The determination of the actual variability of temperature and salinity within the layer is limited by the accuracy of the instrumentation employed. On the other hand, that of oxyty is somewhat higher than would be indicated by the precision associated with the methods used. This is attributed to sampling errors. The determination of the variability should have important bearing on the studies of microstructure in the mixed layer and of surface mixing processes. (Tabata).

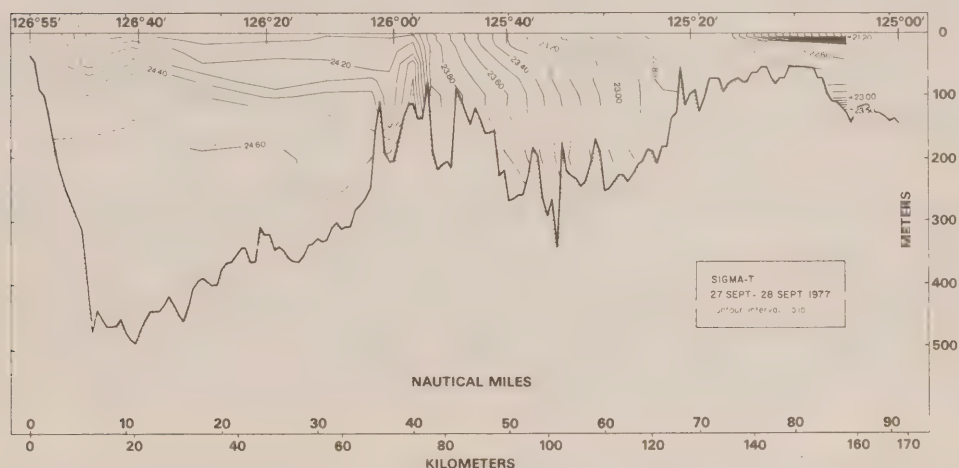
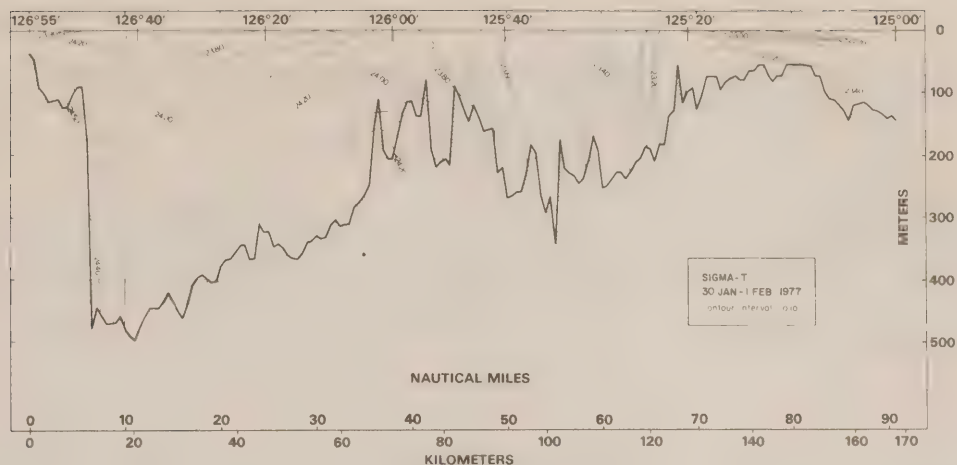
Oceanography of the Continental Shelf

Johnstone Strait Region

Deployment of six current meter moorings in the vicinity of the Newcastle sill in Johnstone Strait during June completed our investigation of the physical oceanography of the Johnstone Strait region. In conjunction with the Tides and Currents section $1\frac{1}{2}$ years of data have been collected at approximately 3 month intervals from the northern Strait of Georgia to Queen Charlotte Strait. Most of these data have now been reduced and plotted and should be ready for presentation in atlas form by mid-1979. (Thomson).

Currents and density profiles obtained near the Newcastle sill in Johnstone Strait are being analyzed in terms of a seaward progressive internal tide. This baroclinic motion appears to be dominated by the first vertical mode with a considerably smaller second mode. The superposition of mean-estuarine flow, barotropic tidal current and the first two baroclinic modes accounts for all but a few percent of the flow variance. This work should be completed for publication in 1979. (Thomson).

Side scan sonar tracks have revealed the presence of a sand-ripple patch extending 2 km seaward of the base of Newcastle sill in Johnstone Strait (Fig.). The sand waves are about 1 metre high and have wavelengths of order 100 metres. An investigation with the *Pisces IV* submersible revealed that the crests were oriented at an angle to the tidal currents and that there is no superficial difference in sediment type between the rippled and non-rippled areas. Work is continuing with Tides and Currents Section and the Pacific Geoscience Centre on this project.



Examples of longitudinal sections of water density (sigma-t) along the inside passage between northern Vancouver Island and the mainland. Sections run from Alert Bay (Broughton Strait) on the left to Cape Mudge (Strait of Georgia) on the right.

Southern Strait of Georgia

In conjunction with the Tides and Currents section and Numerical Modelling section, a four month investigation of the currents and physical oceanography of the Boundary Passage Region was undertaken. As part of joint effort with Pacific Marine Environment Laboratory, Seattle, the work was also extended to include current measurements off Race Rocks and CTD profiles from Cape Flattery to Texada Island in the Strait of Georgia. Data has been reduced but not analyzed.

NUMERICAL MODELLING SECTION

R.W. Stewart - Head

P.B. Crean

R.F. Henry

P.J. Richards - Computing Services

*T.S. Murty

M.G. Foreman - Computing Services

J. Stronach (Postdoctoral Fellow)

*Joined in 1978

The section continues to provide support for other groups in the Institute through the development and application of numerical models for simulation of oceanographic conditions in areas of high priority.

Numerical modelling studies of the Georgia/Fuca system in 1978 were characterized by a shifting emphasis from barotropic tides to considerations of the estuarine circulation.

The two dimensional vertically integrated fine grid (2 km mesh) model of the southern part of the system was extended into the northern Strait of Georgia, partly to provide input to an extended version of the "upper layer" buoyant-spreading model of the Fraser River plume, and partly with a view to performing studies of residual circulation induced by the barotropic tide. It presently appears that further aspects of the barotropic tidal work, primarily concerned with local coastal engineering applications, will be carried out in the private sector.

Work on the "upper layer" buoyant-spreading model of the Fraser River plume continued with an extension of the coastal boundaries to conform to those of the existing fine grid model in the southern Strait of Georgia and the use of full mixed tides. Field work, using the Canadian Hydrographic Survey Launch *Brisk* included STD and current measurements in the region of the shallow banks around the river mouth and time series observations at an anchor station located in the central region of the plume. This is a joint project with J. Stronach and P. LeBlond of the Institute of Oceanography, UBC.

Preparatory to extending these studies to other aspects of the estuarine circulation, a program was developed which will specify the complete indexing system for three-dimensional calculations from an existing schematized coastline and mesh depths as employed in a conventional vertically integrated two-dimensional model. Sensitivity trials are proceeding with a laterally-integrated two-dimensional scheme (vertical and horizontal space dimensions) to examine the adjustments of coefficients required to give realistic longitudinal distributions of scalar and vector properties through Juan de Fuca Strait and the Strait of Georgia.

Joint field programs associated with these numerical model studies involved the verification of a large (5-10 km) eddy which was predicted by the model to form on a flooding tide at the southern end of Haro Strait. Confirmation was also obtained of the existence of comparable eddies in the vicinity of Race Rocks and East Point (with S. Huggett and J. Gower). These eddies are located along the major route seaward for fresh water discharge entering the Strait of Georgia from the Fraser River and are associated with strong local residual circulations. A further program with S. Huggett and R. Thomson, involved two one-week cruises in which time series patterns of CSTD profiles were obtained in the vicinity of an array of five current meter moorings located in the deep channel at the southern end of the Strait of Georgia. The important aim in this work is to provide data which will be used in the design of subsequent numerical calculations, involving deep salt water intrusions. (Crean).

A numerical model of barotropic tides in the channel system forming the approaches to Kitimat was carried out under contract, with Numerical Modelling staff advising on data analysis and modelling techniques.

Investigation continued into the feasibility of including negative eddy viscosity in a barotropic ocean circulation model in order to simulate the transfer of energy to barotropic motion from baroclinic processes.

Internal Kelvin waves in a narrow fjord have been modelled successfully using a new open-boundary technique which permits driving a model by incoming travelling waves. Substantial effort has been put into new numerical methods, in particular, extension of the above travelling-wave driving to more general two-dimensional long-wave problems. (Henry).

A one-dimensional two-layer model is under development for study of the conditions producing internal hydraulic jumps at fjord sills during tidal inflow and outflow. This work has been undertaken in conjunction with the investigation by Coastal Zone Oceanography Section of the dynamics of fjord circulation. Some special features of these models attempted the inclusion of the non-hydrostatic pressure field and the possible use of density as the vertical coordinate. The models will be compared with data taken by the Coastal Oceanography Section in Babine Lake, Knight Inlet and in laboratory experiments.

Two different analytical models were used to simulate the water waves in Kitimat Inlet due to the submarine slide of 27 April 1975. This work is in support of the activities of the tides and water levels group. Scientific direction of two modelling projects sponsored by Petrocan in connection with the Baffin Bay study was undertaken. One is concerned with wind-driven circulation in Lancaster Sound, the other with tidal motion in Baffin Bay. (Murty).

REMOTE SENSING SECTION

J.F.R. Gower - Head

J. S. Wallace

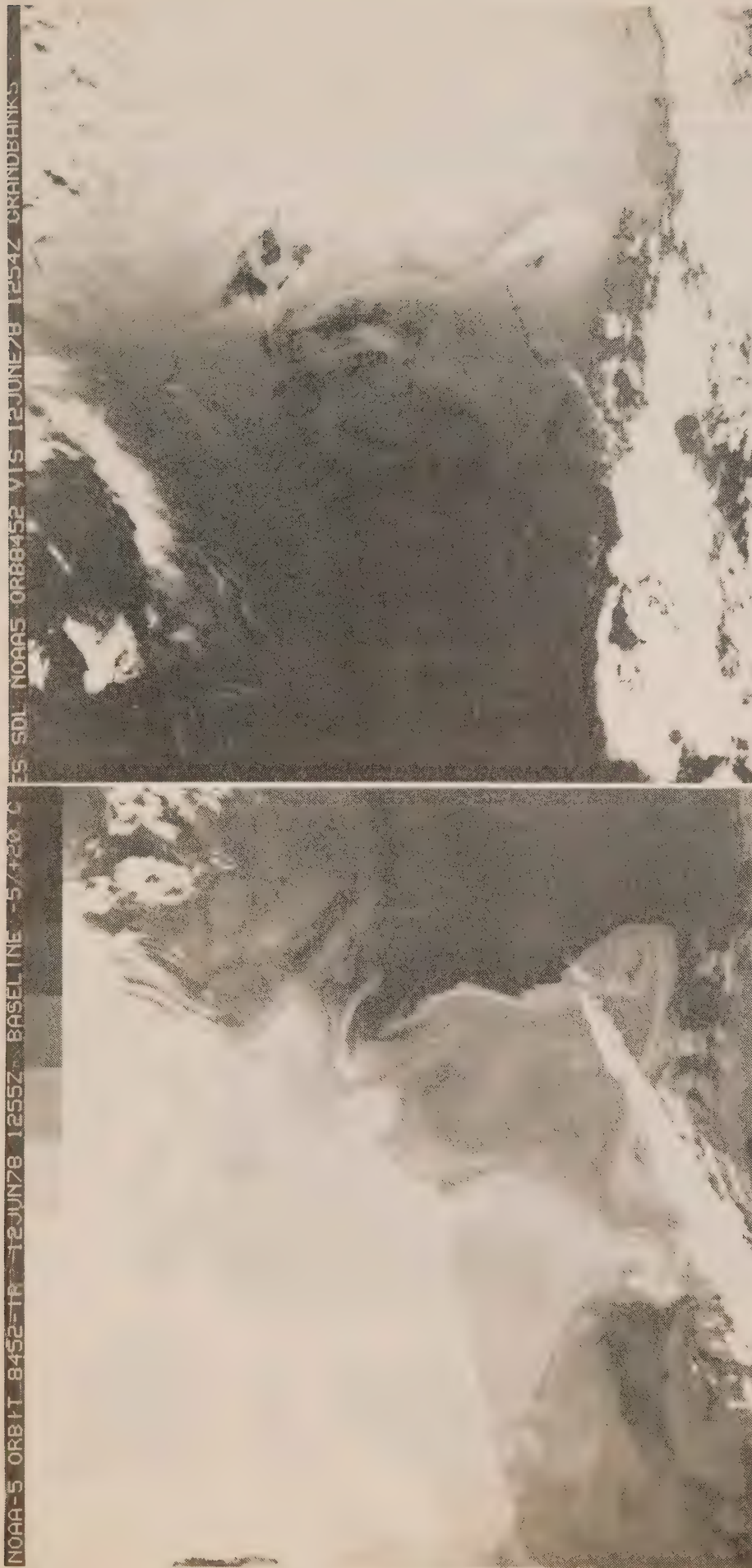
The remote sensing section has responsibility for development of remote sensing techniques for oceanography and for evaluation of techniques originating elsewhere.

During 1978 the international focus for oceanographic remote sensing was on two U.S. satellites due to be launched during the summer months. One, SEASAT would carry 4 microwave instruments designed to map sea surface wave patterns, surface winds, temperature and geoid level. The other, Nimbus G, would carry a water colour scanner designed to measure the near surface plankton concentration. The measurements would in some cases be only approximate, and in other cases be averages over large areas, but the world wide coverage provided by these satellites promised an interesting change in our view of the world.

The launch of Nimbus G increased worldwide interest in water colour mapping. Since 1975, the Remote Sensing Section at the Institute has been making airborne measurements of water colour of the same kind that Nimbus G now makes from space. Our work has concentrated on local water properties with the purpose of mapping primary productivity in coastal inlets and over the continental shelf. At an international colloquium hosted by the section at the Institute in June, our work and that of groups from Europe and the U.S. were compared. Our results stood up well to the test, and the fluorescence measurements that we had been concentrating on attracted considerable attention. A report on the discussions at the colloquium, which also covered a variety of other topics under the title "Passive Radiometry of the Ocean" is available as an Institute report.

Further water colour measurements were taken during 1978 and compared with simultaneous shipdeterminations of chlorophyll profiles in the water to extend our knowledge and experience of B.C. coastal waters. Properties of the fluorescent emission were studied in high chlorophyll levels achieved by growing a plankton bloom or "red tide" in a large open air tank at the Institute. Next summer we hope to extend the work with repeated surveys off the continental shelf and with an Arctic experiment in Lancaster Sound. Both these areas will be covered by Nimbus G at the same time from space.

Several teams of scientists have been organized by NASA to conduct experiments on the accuracy of usefulness of the SEASAT-A instruments. J.F.R. Gower is a member of the Synthetic Aperture Radar team and is involved in an experiment to use this instrument for mapping of coastal B.C. waters looking, in particular, at surface effects of internal wave patterns. The



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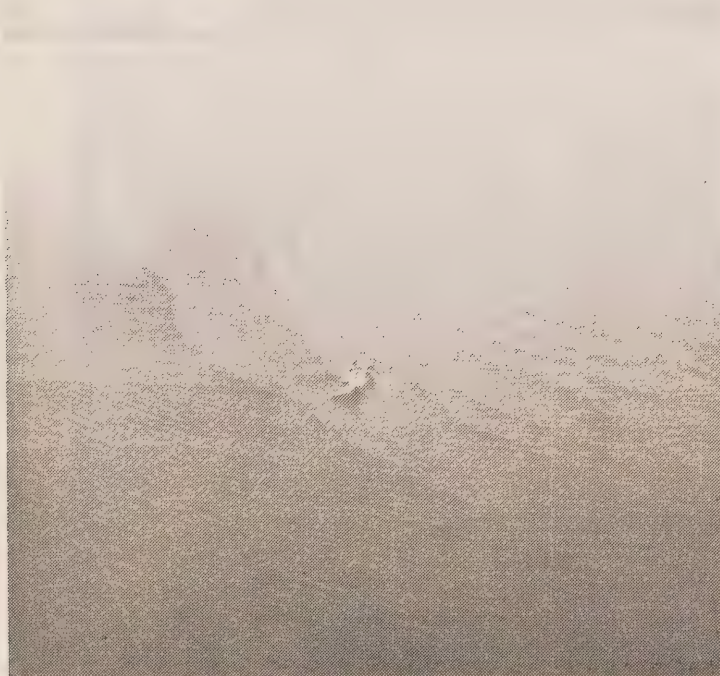
B

A pair of satellite images taken at the same time by the NOAA weather satellite, NOAA5. A, the thermal infrared, maps water temperatures and shows a tongue of cold water extending down into the Gulf Stream. B, the visible, shows reflected sunlight (sunglint) which indicates roughness changes in the cold and the warm water. The Remote Sensing section at IOS is involved in an experiment to map these variations with the SEASAT orbiting radar.

internal waves produce characteristic bands of roughened water whose slopes were measured using a laser instrument mounted on the research vessel

Endeavour. This experiment is designed to test theories of radar imagery as well as to study the waves and their movements. We are also involved in an experiment to map the structure of the Gulf Stream looking at surface effects induced by the thermal or dynamic properties of the current. The Gulf Stream causes roughness variations by heating the lower (boundary) layer of the atmosphere and also by deflecting surface waves along the current boundary. Roughness variations over the current have been seen in sunglint recorded by U.S. NOAA weather satellites. Although the satellite has now stopped working (due to a failure in the slip rings which carry power from the solar panels) radar data was collected over both experiment test sites. The data needs complicated processing and has still not been released, but other types of pictures of the patterns being studied are included in this report.

Other projects undertaken by the Remote Sensing section include surface current mapping by tracking drogues from an aircraft equipped with an inertial navigation system. Several such flights were made as part of a test of new low frequency coherent radar designed to map surface currents over a large area. Preliminary tests were also made on possible oceanographic uses of the new coast guard vehicle traffic management system which consists of a network of radar stations covering the approaches to Vancouver and Victoria.



An airphoto of the research vessel "Endeavour" making measurements of an internal wave packet in Georgia Strait. Airborne and satellite images taken at the same time will be used to test theories of the radar imagery process and to evaluate the radar for future oceanographic programs.

ARCTIC MARINE SCIENCE

A. R. Milne - Head

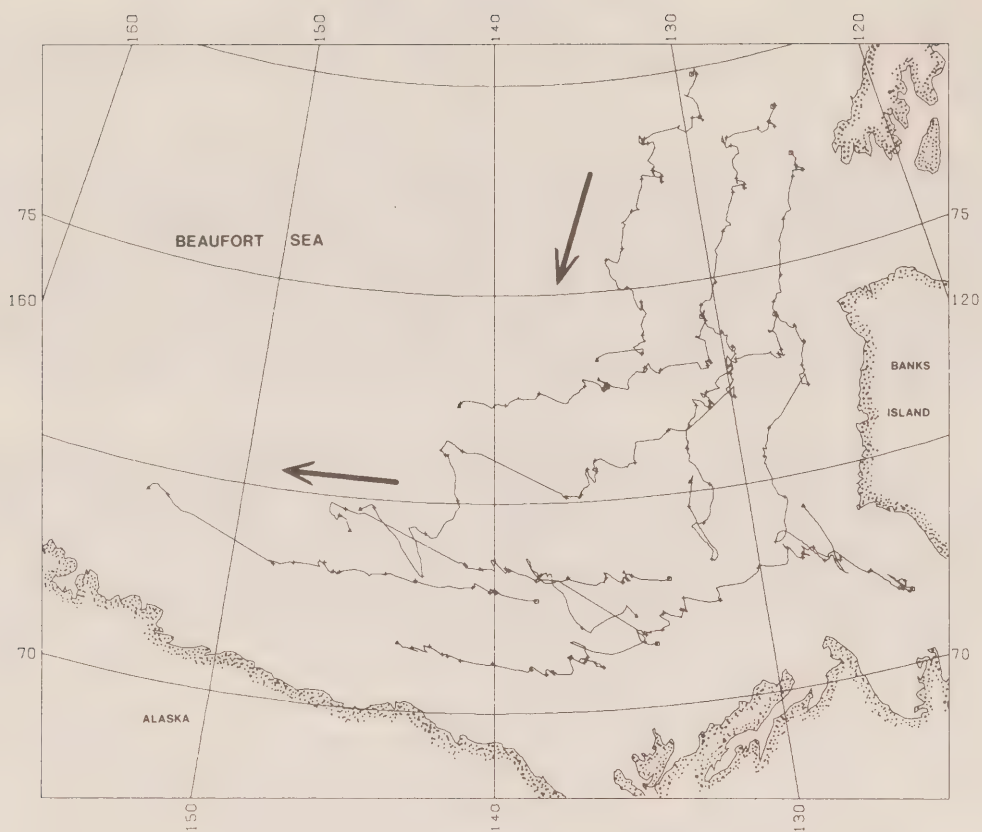
B. D. Smiley H. Melling (Postdoctoral Fellow) R. H. Herlinveaux

The Beaufort Sea and Parry Channel were our geographic focus of interest during 1978. The joint "government/industry" Beaufort Sea Project continues to distribute technical and environmental information through the Institute library. Three of the projected six Overview Reports have been published for general readership; the remainder - in various stages of drafting and editing - will be published before the Project's close-down date in mid-year, 1979. Other research activities of the group concerned problems of proposed industrial development of offshore gas and oil.

In January and early March, 1978, fifteen Random-Access Measurement System Data Buoys were air-dropped on to the offshore Beaufort Sea ice. Throughout the winter, they transmitted positions to the NIMBUS-6 satellite until, one by one, the buoys ceased reporting as a result of being crushed by ice or through failure. One exceptionally durable buoy operated until late October having travelled about 800 km on an erratic path from Banks Island to a position near Point Barrow, Alaska. Two of the buoys carried air-pressure sensors which, together with NOAA satellite imagery, will aid the interpretation of Beaufort Sea ice drift. This study has nicely verified the speculated clockwise drift of the offshore pack ice, at speeds of up to 1.5 km/hour. A major study addressed the environmental hazards of offshore drilling in Lancaster Sound. The subsequent report (which stressed the hazards of icebergs and strong currents to drillships, as well as the threat to the marine wildlife from oil pollution), has assisted the Department of Indian and Northern Affairs and the Federal Environmental Assessment Review Panel in judging the acceptability of the application by Norlands Petroleum to drill exploratory wells.



Random-Access
Measurement
System (RAMS)
Data Buoy
readied for
air-dropping.



RAMS Data Buoy movements from 15 January to 11 September 1978

A second proposed study reviewed the environmental hazards of the year-round transport of liquid natural gas, by icebreaker, through Parry Channel. The novelty of this industrial endeavour (called the Arctic Pilot Project) taxes our ability to make even rough predictions of impact to resident and migrant seabirds, seals, polar bears and whales. The report will be published in early 1979.

Icebergs in eastern Lancaster Sound were followed by radar atop the 450 metre-high Hope Monument, on southeastern Devon Island. This cooperative study with Petro Canada Limited was conducted by Seakem Oceanography Limited. Their finds indicate that, from early July to late September, the general circulation of surface waters sweeps ice and icebergs from Baffin Bay into Lancaster Sound. Icebergs commonly travel at speeds of 1.1 km/hour in offshore waters.



Radar Camp at Hope Mountain

There were disappointments in 1978 involving the measurement of ocean currents in Parry Channel. We were unable to recover three overwintered moorings of current meters from the 700 m deep waters of eastern Lancaster Sound. The unsuccessful instrument recovery, resulting from the apparent failure of the acoustic releases, was compounded by late ice break-up and heavily ice-infested waters which hindered the M.V. *Theron*, a Petro Canada charter vessel. Later, under contract to Dobrocky Seatech Limited, we attempted to deploy three overwintering moorings of current meters on the Barrow Sill, north of Somerset Island. Specially designed taut-wire, torsionally-rigid moorings were used in order to compensate for the near-zero magnetic field in this area of the Arctic. Even with Canada's newest icebreaker CCG *Pierre Radisson* serving as the deployment ship, severe ice conditions prevented access to the Sill area. At an alternative location, the near-surface floats attached to the moorings imploded, and the program was aborted. Surprisingly, the imploded floats were improved re-designed substitutes for the aluminum floats which had failed in pre-program testing.

Members of this group often served as advisers to industry and other Government agencies. Advisory tasks included the measurement of water/gas flows in leaking sub-sea wells in the Beaufort Sea, participation in public hearings on offshore drilling in Lancaster Sound, review of the Polar Gas Project and Davis Strait drilling program, management of the Arctic Ocean Dumping program, review of the Arctic Marine Oilspill Program (Environmental Protection Service), management of the Beaufort Sea Contingency Planning Task Force, and the Beaufort Sea Scientific Response Plan. Such roles are not likely to decrease with the current burgeoning of offshore industrial activity in Arctic Canada.

OCEAN CHEMISTRY DIVISION

C.S. Wong - Chief of Division

B. Mathias - Secretary

W.J. Cretney
R.W. Macdonald
J.A.J. Thompson
R.D. Bellegay
W.K. Johnson
F.A. McLaughlin
O.S. Munro

D.W. Paton
D. Macdonald
J.S. Page (Computer Services)
T. Soutar (Chemical Instrumentation)
V. Stukas (Postdoctoral Fellow)
K. Iseki (Postdoctoral Fellow)

Visiting Scientists:

J. Hoff (IOUBC - NRC Fellowship)
K. Kremling (Institut für Meereskunde, Univ. of Kiel, F.R. Germany)
H. Peterssen (Institut für Meereskunde, Univ. of Kiel, F.R. Germany)
E. Bauerfeind (Institut für Meereskunde, Univ. of Kiel, F.R. Germany)
D. Cossa (Rimouski University, Quebec)
J. Piuze (Pêches et Sciences de la Mer, Québec)
R. Schmitt (Schmitt Consultants - F.R. Germany)
K. Vermeer (Canadian Wildlife Service)
B. Imber (Department of Oceanography, University of Liverpool, U.K.)

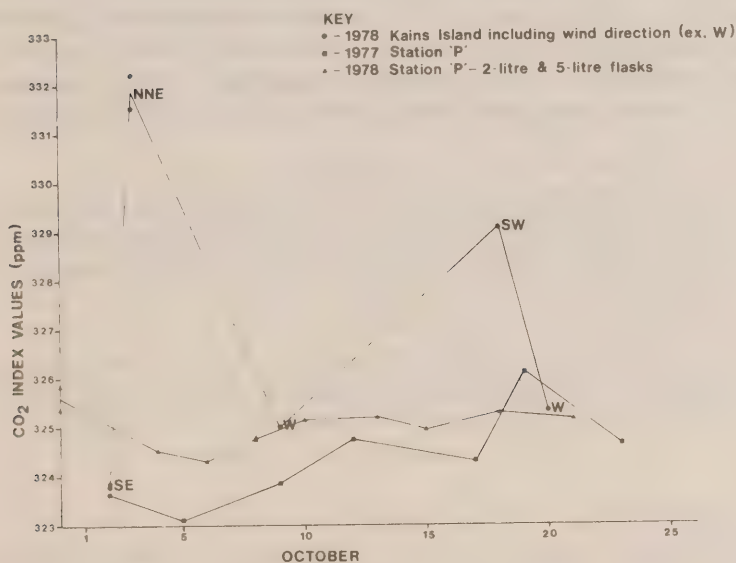
Ocean Chemistry Division's primary responsibility is to understand the chemical aspects of the marine environment in B.C. coastal waters, the western Arctic and N.E. Pacific Ocean and to assess the chemical effects of human activities on seawater, suspended matter and bottom sediments. These effects must be distinguished from large natural and often non-systematic variations. A secondary role is to understand the interaction of the inorganic and organic material in the marine environment with the marine biota and geological reservoirs so as to provide chemical oceanographic information and uptake-release processes useful in fisheries research, in geological studies and in investigations of water transport and mixing.

The Division is actively supporting the Federal Government's Make-or-Buy policy, with over 60% of our effort devoted to contract work. The goal is to assist in the establishment of a self-sustaining and credible capability in private industry to conduct chemical baseline studies in coastal waters, chemical environmental impact assessment and arctic facilities, including ultra-clean laboratories for trace metals and hydrocarbons, heavy isotope mass spectrometer for accurate trace metals measurements, gas chromatograph/mass spectrometer for organic work, and an infrared CO₂ laboratory for the carbon cycle. These facilities enable us to stay at the state-of-the-art of ocean chemistry, with sufficient scientific capability to supervise contracts, scrutinize work performed by the private sector and provide scientific advice to policy-makers in an effective way.

Marine Carbon Cycle

(Wong, Bellegay, Munro, Iseki, Page, Rennie, Soutar, Cornford)

The question of atmospheric CO₂ increase and its possible climatic consequences is perceived as a future international problem. As mankind faces the challenges in the year 2000 with exciting new scientific and technological advances, he is also moving closer to a warning landmark in time, when the possible warming from CO₂ generated by fossil fuel burning may be significantly above the climatic noise level. The scientific community has the urgent challenge to understand the environmental behaviour of CO₂ and to predict reliably the future course of rise in CO₂ levels and an associated increase in atmospheric temperature within this short span of the next 21 years. The on-going research in Ocean Chemistry is contributing to this global international effort by providing insights into the marine aspects of the complex global carbon cycle.



Time series of CO₂ at Ocean Weather Station P and at the lighthouse on Amphitrite Point on western Vancouver Island, where onshore westerlies favour uncontaminated marine air samples.

The major emphasis of our approach is still on time-series measurements of CO₂ over the ocean. The CO₂ time-series at Ocean Weather Station P (50°N 145°W) is in the tenth year of documenting the increase in atmospheric CO₂. In response to a decision of the Canadian government to terminate the weatherships in the near future, replacement programs have been set up on a crash basis in order to have overlap and continuity between the weathership time-series data and the new data. Through cooperation with the Canadian Coast Guard and the Atmospheric Environment Service, weekly air samples were collected at lighthouses at Amphitrite Point and Kains Island on the west coast of Vancouver Island. Moreover, through the assistance of the Montreal Shipping Co. and the Canada Maru, air samples were collected between Victoria and Japan about once per month across the Pacific Ocean. Preliminary results indicated that during periods of onshore winds almost identical values were obtained at Amphitrite Point and at Ocean Weather Station P.

A more critical scrutiny of the contribution from wood burning to atmospheric CO₂ level indicated a smaller value than reported previously, but it still amounts to a significant fraction of about 15% of the present-day burning of coal, gas, petroleum and limestone. This revised lower figure was based on taking into account factors such as incomplete combustion and longer degradation time of buried stumps. The greater lack of present knowledge is determination of the role of detritus reservoirs of carbon both on land and at sea. Continuing work on marine detritus suggested that at Ocean Weather Station P, seasonal fluxes of detritus carbon from surface waters into deep ocean may be a significant mechanism in the carbon budget. Between the winter months (January) and the summer months (July), a four-fold increase of particulate organic carbon was observed at all depths between 0m and 1000m which can be attributed to increased summer productivity and a subsequent increase in particulate carbon transfer.

Considerable effort was devoted to preparation work for the First GARP Global Experiment cruise to the South Pacific in December, 1978. Joint work with Dr. Schmitt of F.R. Germany was supported by NATO for the development of a pCO₂ measuring device using this water-correcting infrared CO₂ analyzer and a seawater equilibration system. This was installed on the C.S.S. *Parizeau* to measure atmospheric and surface seawater pCO₂ continuously between Victoria and Hawaii, then along the cruise track at 155°W to the equatorial Pacific Ocean.

In addition to Station P CO₂ analysis, our infrared laboratory has been performing air CO₂ analysis for other Canadian CO₂ stations at Sable Island in the Atlantic and at Alert in the Canadian Arctic, both manned by the Atmospheric Environment Service.

Steps are being taken to bring the radiocarbon facility on-line in order to process the backlog of Station P samples taken over the past several years.

Trace Metals

(Wong, Kremling, Peterssen, Imber, Piuze, Cossa, Johnson, R.W. Macdonald, D. Macdonald)

The main objective is to assess the natural and anthropogenic inputs of physiologically significant trace metals into the marine environment and their interaction with suspended matter, the planktonic biota and surface sediments.

A serious gap in knowledge exists between marine chemists engaged in attaining meaningful levels of trace metals in seawater and those working on modelling of chemical speciation and biological effects of trace metals. The latter groups often select unrealistically high levels of trace metals based on literature values obtained prior to the availability of reliable techniques. To narrow this gap, Ocean Chemistry is carrying out a co-operative study with Dr. Kremling's group at the Institut für Meereskunde at Kiel, F.R. Germany and Professor Riley's group at Liverpool, U.K., on accurate measurement of trace metals in seawater, funded by NATO. An intercomparison of sampling devices and analytical techniques was carried out in August using a small CEPEX (Controlled Ecosystem Population Experiment) enclosure of 65,000 litres of seawater in Saanich Inlet, B.C.

The seawater collected was processed and analyzed in clean rooms. Preliminary results indicated the failure of commonly-used samplers to capture representative water samples at the desired depth. The results also suggested the availability of analytical methods of sufficient precision in the case of copper, nickel, lead and cobalt but not so for cadmium, mercury, iron and zinc. (Wong, Kremling, Johnson, Peterssen, Imber, Stukas, Berrang, Erickson, Thomas).

The ultra-clean laboratory specifically designed for ultra-trace metal work was put into operation about half a year after our move to Patricia Bay. This unique laboratory consists of three areas: entrance room, instrument room, and preparation and processing room. All are maintained under positive pressure with filtered air which has undergone 99.97% removal of 0.3 micron and larger sized particles. This unique facility is being utilized to develop accurate techniques for lead, mercury, cadmium and other trace metals in sea water and to develop "standard sea water" for trace metals representative of natural levels using Ocean Weather Station P sea water. This work is currently funded by NATO and possibly will cooperate later with the NRC Atlantic Region Laboratory. Recent work using a clean room showed that in Saanich Inlet and in the Strait of Georgia, total lead in sea water is of the order 20 ng kg^{-1} which is considerably less than levels obtained previously without using cleanroom techniques. (Stukas, Johnson, Wong).

Use of tetraethyl lead in gasoline has produced a serious environmental problem. Supported by Environmental Contaminants contract funds, the pathways, fate and behaviour of tetraethyl lead in the marine environment were investigated using three 65,000 litre C.E.P.E.X. enclosures spiked with 0, 5 and 50×10^{-9} of tetraethyl lead. The compound showed marked biological effects on the planktonic community, as indicated by a decrease in C-14 productivity, chlorophyll-a, drastically at the 50×10^{-9} level. However, natural processes quickly removed this compound from both sea water and particulates with the system reverting back to background concentration levels within 6-10 days. (Stukas, Wong).

Utilizing the most recent improvements in techniques to extract multi-elements from sea water based on the Danielsson method of University of Göteborg, long-term storage tests were carried out for sea water. With this improved method for mercury, the level of total mercury in Saanich Inlet was found to be extremely low at 5-6 ng kg^{-1} of seawater. (Johnson, Wong).

Knowledge of the rates of release and accumulation of trace metals is important to Ocean and Aquatic Sciences in managing the Ocean Dumping Control Act. In light of recent advances in both chemical methodology and marine chemical research Ocean Chemistry has initiated the first of a series of chemical studies to determine the validity of existing criteria regarding permissible maximum quantities and concentrations of toxic compounds in the dumped material presently specified under the Act. The first experiment was designed to examine the variability in analytical results on dredged spoils taken from Victoria Harbour and loaded on ocean dumping barges. Ambiguity in wording and loopholes in the Act were found. For example, mercury values from a small number of samples (two in this case) were within the present 0.75 mg kg^{-1} limit. However, the average obtained from analysis of 40 samples was 1.90 mg kg^{-1} , far in excess of the present limit. Study is underway to define the dimensions of the revision required for the regulations. Chemical variability of samples from the same dumping barge and

between different barges was also investigated. Statistical analyses indicated a small but distinct difference between pre-dredged samples and those from four barges, for analyses of copper, iron, lead, zinc, cadmium, chromium, mercury, arsenic, organic carbon and organic matter. To improve the effectiveness of regulations, a selective extraction scheme for trace metals from marine sediment and dumped material was designed and contract laboratory studies were carried out to test the scheme. We hope this may lead to a new set of ocean dumping criteria for assessing the impact of trace metals, based on accumulation and release rates. (R.W. Macdonald, Wong).

A C.E.P.E.X. experiment was conducted in July to study the oxygenation and removal rate of Mn(II) and Fe(II) under natural conditions. Copper and cadmium ions were added to investigate the removal of these trace metals on precipitated manganese and iron-oxyhydrates. Preliminary field results indicated a very rapid rate of removal of iron and manganese from the water column within days of their addition rather than periods as long as weeks or months which had been indicated in previous laboratory experiments. (Kremling, Peterssen, Munro, Johnson, Wong).

Marine Hydrocarbons and PCBs

(Cretney, McLaughlin, R.W. Macdonald, Wong, Bauerfeind)

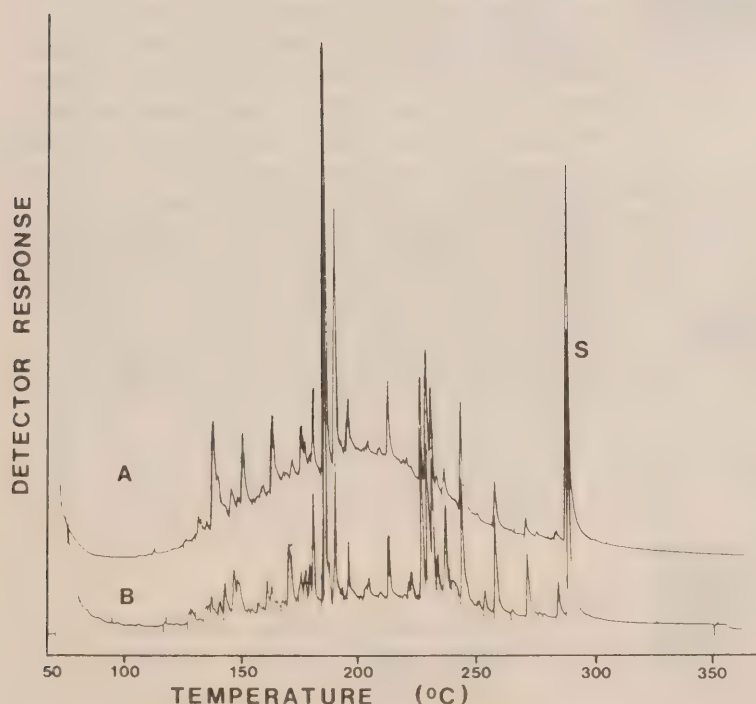
The objective of this program is to understand the occurrence, pathways, and fate of hydrocarbons (natural, petroleum, polychlorinated biphenyls and pesticides) in the marine environment. The main effort was devoted to a C.E.P.E.X. study of the behaviour of PCBs in the marine environment and to a Kitimat baseline study.

As in the case of trace metals, a unique clean room has been established for study of trace hydrocarbons. The clean room, consisting of entrance laboratory, instrument room with gas chromatographs, a gas chromatograph/mass spectrometer, and a high performance liquid chromatograph, and a preparation room, has 99.97% of particulates larger than 0.3 microns diameter removed by high efficiency filtration. Early in the year, joint work was performed with the NRC Atlantic Region Laboratory on a hydrocarbons sampler intercomparison study using a C.E.P.E.X. enclosure. (Cretney, McLaughlin)

PCBs, because of their persistence and toxicity in the environment, have been placed on the prohibited list of the Environmental Contaminants Act. Supported by Environmental Contaminants contract funds, a systematic study was carried out to understand the behaviour, pathways, residence time and sub-lethal toxic effects of PCBs in the marine environment using C.E.P.E.X. 65000 liter enclosures in Saanich Inlet, B.C. In August, 3 bags were launched and spiked with 0, 5 and 50×10^{-9} of PCBs (Monsanto Arochlor 1254) and observations were continued for 28 days. Preliminary results indicated that the overall effects of PCBs on phytoplankton were similar to those from other types of hydrocarbons, with the initial diatom population being replaced mainly by microflagellates. There was also a marked effect on the zooplankton population (Paracalanus parvus adults and copepodites mainly). PCBs were quickly removed as settling particulate material with 50% removal in 3-5 days and 90% removal in 10 days. Another PCBs study was carried out in connection with the Ocean Dumping Control Act. A contract was let to test the

statistical validity of permitting the use of only the "usual" small number of PCBs analyses now performed to satisfy a permit application, against requiring the average of a large number of measurements on the same batch of samples. Preliminary results indicated the PCBs measurements were highly variable. (Macdonald, Wong, Cretney, Bauerfeind).

Coastal waters in northwestern B.C. are within a region where high industrial growth is expected in future. There has been serious environmental controversy regarding the siting of an oil port at Kitimat to receive Alaska crude shipments. A terminal for shipping Alberta wheat to China was proposed recently for Prince Rupert. Ocean Chemistry is supervising a contract baseline study in this environmentally sensitive area. Two chemical oceanographic cruises were conducted in the Kitimat Harbour, Douglas Channel and approaches: one June 19-29, and another October 18-27. Standard chemical oceanographic stations (T, S, O₂, nutrients, and CTD casts) were carried out together with Neuston-net tows for debris and tarballs, SCOR-net tows for plankton, surface sediment sampling for lead-210 dating and hydrocarbons, trace metals analyses, and the collection of intertidal mussels for hydrocarbon study. Preliminary results indicated very high concentrations of polyaromatic hydrocarbons in the sediment near the north side of the Kitimat Harbour (up to 1 mg kg⁻¹ of pyrene), possibly due to production of fluoroaromatics during the electrolysis process in aluminum production. This difference in polyaromatics by one to two orders of magnitude between sediments from the approaches and the Kitimat Harbour itself may be a matter of serious concern. Further work is being done to assess the contribution of polyaromatics to carcinoma in the mussel, Mytilus edulis. (Wong, Cretney, Macdonald, McLaughlin).



Gas chromatograms of non-polar hydrocarbons in sediments from Kitimat Harbour (A) and nearby Kildala Arm (B). The pronounced "hump" in A is characteristic of hydrocarbon pollution. S = internal standard.

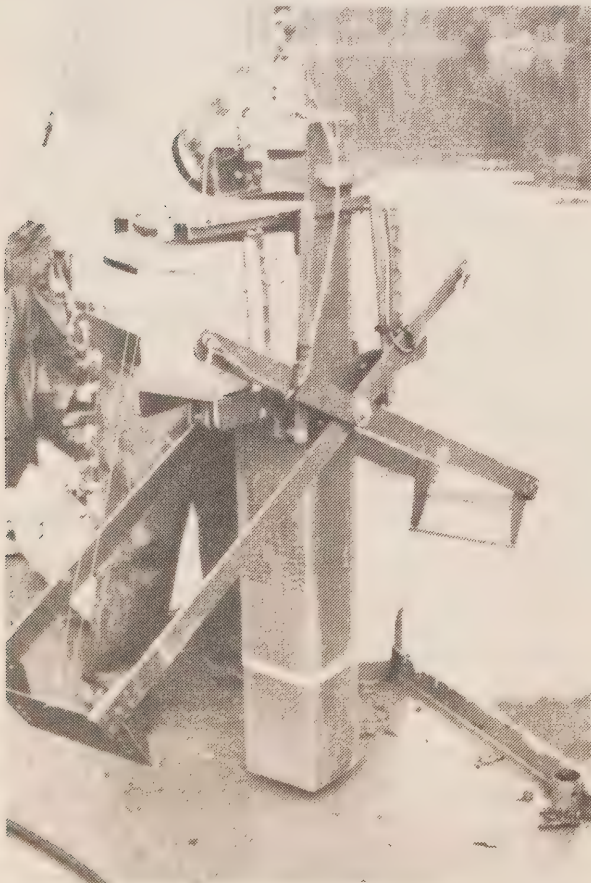
Cooperative work was carried out with Dr. Vermeer's group at Canada Wildlife Service to study tarballs washed up on beaches at Triangle Island situated at the northern tip of Vancouver Island. There may be reason for concern if the tar was derived from increased tanker traffic. However, preliminary hydrocarbon analyses indicated the origin of the tar to be from bilges rather than from crude oil of the Alaska type. (Wong, Cretney, Vermeer).

Coastal Pollution

(Thompson, Paton, Hoff)

Mining is one of major industries in B.C. Its tailings disposal is of great concern to the environment departments of the provincial and federal governments. Recently, public hearings were held on the environmental impact of mine tailings disposal from copper and lead ores into B.C. coastal fjords and on the issue of re-opening of old B.C. molybdenum mines in future.

Joint work was conducted with EPS in waters off northern Vancouver Island to monitor the environmental effects of mine tailings. During the month of September, a joint cruise was carried out in the Rupert, Holberg and Quatsino area to collect sediment samples and pore waters, arsenic methylation samples and samples for tailings distribution. An in-situ experiment was initiated with EPS to utilize M. edulis, a mussel commonly found along the coasts, as an indicator of particulate copper uptake in the Rupert Inlet.



Another nine-day cruise was conducted in mid-October to collect sediment samples for study of the methylation of lead and to collect core samples in Alice Arm and Hastings Arm for tailings distribution studies. Some analytical work was done to determine the copper and zinc distribution in sediment cores from Rupert and Holberg Inlets and for earlier cores in 1975 from Texada Mine. The Texada Mine tailings showed clearly defined dispersion and had the highest copper content observed so far in tailings analyses, at a concentration of 1600 mg copper kg⁻¹ of sediment. (Thompson, Paton; Goyette of EPS)

Box corer being prepared for cast - Rupert Inlet, September 1978.



Sediment Tailings Interface - Rupert Inlet, September 1978

To determine the extent of methylation of metals occurring in marine sediments, studies were conducted in the Alice Arm area by contract on methylation of arsenic (funded under the Environmental Contaminants Act) in the Alice Arm area on methylation of lead (supported by Ocean Dumping funds) and in the Howe Sound and Port Alberni area on methylation of mercury (also supported by Ocean Dumping funds). The production of methyl mercury appeared to be as great as that detected in the Port Alberni sediment despite higher organic loadings there. Methyl mercury was degraded at a much more rapid rate than anticipated in marine sediments. Rates of demethylation are temperature dependent. It appears that organisms responsible for demethylation are less efficient at lower temperatures relative to methylating organisms. (Thompson, Paton).

In August, a two-day cruise was undertaken to collect benthic samples at the Macaulay Point outfall, a relatively polluted area, and at Clover Point, where background environmental data should be collected prior to completion of the sewer line extension into deeper waters. (Thompson, Paton).

Laboratory study was initiated on the release of trace metals from mine tailings in sea water, using a multi-element extraction technique modified from Danielsen's method for copper, zinc, lead, cadmium, iron, nickel, cobalt and manganese. (Hoff, Thompson, Wong).

Amundsen Gulf

Ocean Chemistry Division participated in the C.S.S. *Parizeau* Amundsen Gulf cruise on a ship-of-opportunity basis, to collect sea water samples and surface sediments. Due to unfavourable ice condition and a tight schedule, only three stations were occupied out of ten planned. (D. Macdonald, R.W. Macdonald).

Weathership Program

Open-ocean effort was devoted to a continuing study of the long-term trends of chemical parameters at Ocean Weather Station P (50°N, 145°W). Neuston-net tows were made between Victoria and Station P to collect tarballs and other surface pollutants. Weekly samples of atmospheric CO₂, surface alkalinity, total CO₂ and surface radiocarbon were taken together with some continuous shipboard infrared measurements of marine air CO₂ and pCO₂. Samples of nutrients were taken to provide information about long term fluctuations and their relationship to circulation and the marine food chain. Particulate detritus organic carbon samples were collected on the *Quadra* cruises. An examination of storage techniques for nutrients was initiated by collecting large water samples in a variety of locations. Multiple replicate runs onboard ship allowed accurate determination of the nutrient concentrations and the precision of the automated analysis. The effect of filtering, quick or slow freezing and storage time is currently under investigation by analyzing portions of batched samples at various time intervals. (Bellegay, Wong, R.W. Macdonald, McLaughlin).

OCEAN ECOLOGY LABORATORY

R.O. Brinkhurst - Head

M.J. Austin	G. Gardner (Postdoctoral Fellow)
K. Denman	P. Chapman (Graduate Student)
D. Mackas (Postdoctoral Fellow)	
+ S. Hill	

+Joined during 1978

This year the laboratory gained two new positions which have been filled by Steve Hill and Dave Mackas. Grant Gardner stayed on under contract at the end of his fellowship to complete his zooplankton studies.

Lengthy negotiations on the ship-of-opportunity segment of the Pelagic Ecosystem Prediction project were successfully completed with the award of an unsolicited proposal contract to Seakem Oceanography. Six cruises on a track between Howe Sound and Tahsis Inlet will be conducted during the early part of 1979 using a duplicate plankton sampler of the type developed by Dave Mackas. We will be cooperating with the Remote Sensing Section for airborne surveillance of various parameters on either side of the ship track. We have also spent considerable time assembling equipment and planning our in-house research contribution to the project via cooperative studies on the shelf with Hydrography and Ocean Physics. The pilot project for the ship-of-opportunity study using the Imperial Oil tankers is underway, funded by Dr. T.R. Parsons (IOUBC) and housed at the Institute.

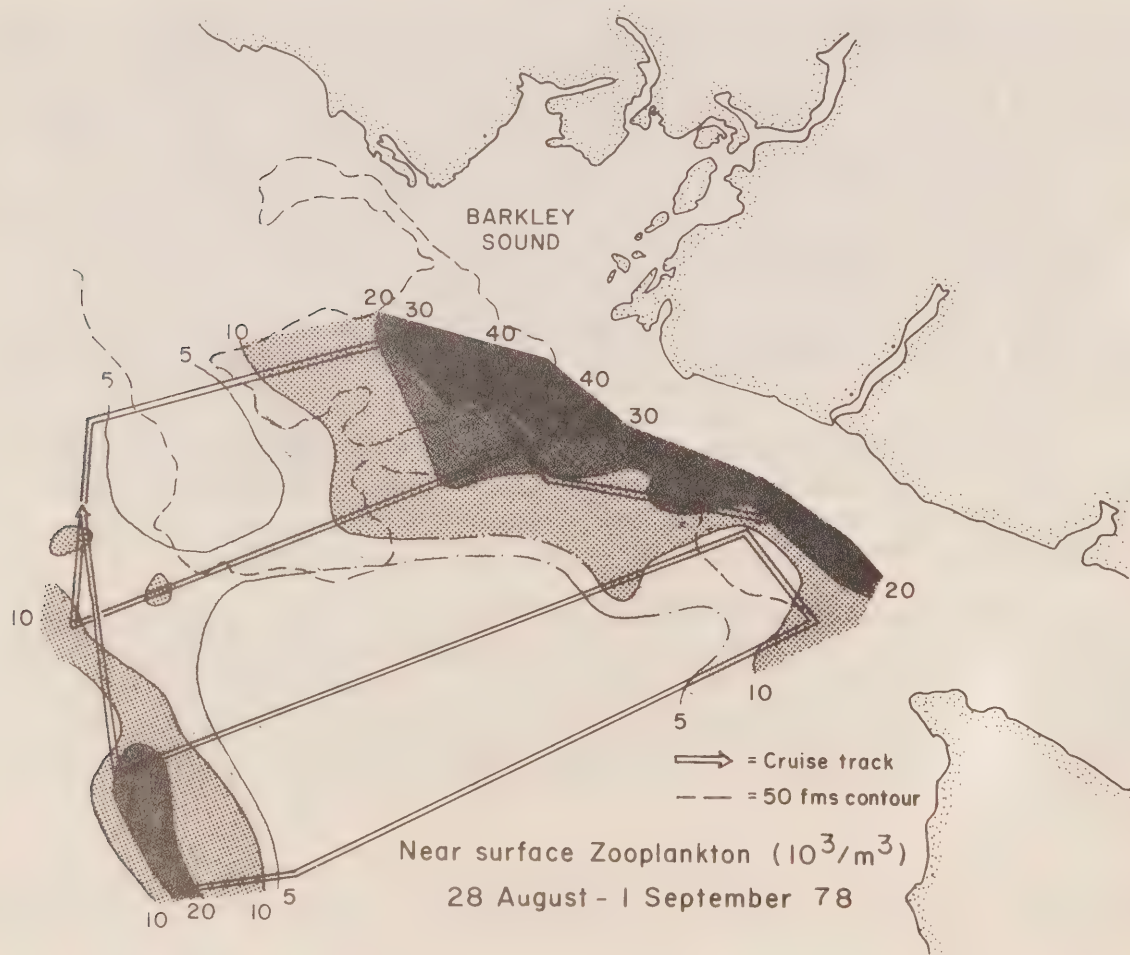
Another unsolicited proposal has resulted in a contract being signed with T. Beak and Co. in Toronto to test theories related to the activity of sludge worms in churning sediments and returning heavy metals to the environment when they might otherwise have remained buried.

The laboratory provided the largest part of the organization of the American Society of Limnology and Oceanography summer meeting in Victoria which was co-hosted by the Institute of Ocean Sciences and the University of Victoria. About 800 people enjoyed good weather, good company and stimulating science and the meeting has been acknowledged as a success. It certainly helped to publicize the work of the Institute, especially in the biological community.

During 1978, our work was assisted by a variety of people working under F.L.I.P. (Federal Labour Intensive Program) summer student positions and under contract.

Dr. Brinkhurst continued to administer the OAS, Pacific Region contribution to the Ocean Dumping program, looking after the review of dumping applications, the reporting work involved and supervision of the research contracts with the help of Bob Smith, the Institute Industrial Liaison Officer.

Dr. D. Mackas led a series of cruises in B.C. coastal waters designed to locate, map, and explore the biological and physical dynamics of various regions of high plankton production and standing stock. The cruises concentrated on continuous underway sampling using Ocean Ecology's automated plankton counting system. The areas surveyed were Georgia Strait (May, July), the continental shelf south and west of Barkley Sound (August), and Queen Charlotte Sound and the mainland inlets (October cruise led by Dr. Gardner). Strong plankton aggregations were found, typically forming a banded pattern oriented parallel to the local bathymetry. Mackas was also involved with organization of the Victoria ASLO meetings, and presented results of his 1977 work from the Canada-Peru ICANE project.



Plot of Zooplankton Distribution off B.C. Coast From the Mackas Counter

Dr. G. Gardner's survey of British Columbia coastal marine zooplankton is progressing well. The last of four major cruises was completed in October, and data from the whole set of cruises are now being analyzed. A preliminary analysis of the whole data set, and a more complete analysis of the data from the first two cruises, will be completed by the end of the fiscal year 78/79. To date, the sampling areas have been subdivided into regions defined by similar temperature/salinity characteristics. To a large extent the same station groupings have been derived from the observed species distribution patterns. This supports the assumption that physically definable regions can be characterized by unique assemblages of zooplankton. This information is important to our understanding of the mechanisms by which different zooplankton communities are formed and maintained. Such information regarding large scale variations in zooplankton community composition can be of considerable use to studies of the production of salmon and other commercially important species. (Mackas, Gardner).

In cooperation with Terry Curran of Institute Electronics, Ocean Ecology has developed a vertical profiling instrument system to complement the continuous flow-through instrumentation used by Dr. Mackas for horizontal mapping. When completed the package will include a conductivity-temperature-depth (CTD) probe, a rosette bottle sampler, an in-situ fluorometer, a beam transmissometer and a dissolved oxygen meter. We have also acquired a desktop computer for both logging and near real time graphical display of the data.

The new system is to be used on the west side of Vancouver Island during the cooperative study of the continental shelf waters to be jointly conducted in 1979 by Ocean Ecology, Ocean Physics, and Tides and Currents. It will allow us to sample the fine scale vertical structure of several variables as the instrument is lowered through the water. Based on the observed structure, the rosette bottles will be tripped at the desired depths as the instrument is raised back to the surface. The water from the bottles will be used for phytoplankton identification, nutrient analyses, routine chlorophyll, salinity and oxygen calibrations. The data will be used to study the effect of vertical and horizontal transport of nutrients and phytoplankton on the productivity of the phytoplankton and zooplankton. (Denman, Hill).

In benthos studies, Peter Chapman finished his field study of the North Arm of the Fraser River. Results show salinity in the sediments changes seasonally but not daily despite the diurnal changes in the water column due to tides. The benthos moves alternately seaward and landward during the year in response to the dominant annual flow pattern of the river.

The distribution of aquatic oligochaetes (sludge worms) is under continuous review based upon observations in both local coastal localities and on a world-wide basis as collections are made available. The explosion of knowledge on marine species has led to active collaboration with a number of colleagues which will culminate in the first International Symposium on Aquatic Oligochaete Biology to be held at the Institute in 1979. Planning for this has been totally in the hands of Ralph Brinkhurst for a year or more.

SHIP DIVISION

E.N. Geldart - Regional Marine Superintendent

N. St. C. Norton - Assistant Marine Superintendent (Deck)

R.W. Parkinson - Assistant Marine Superintendent (Eng.)

D.J. Redman - Design Draftsman

D.A. Doyle - Secretary

The Pacific Region Ship Division provided ship, submersible, launch and depot support for the 1978 hydrographic and scientific programs and for several federal departments and universities.

CSS *PARIZEAU* (64.3 m overall, 1929 tonnes)

Master: A.G. Chamberlain

Chief Engineer: P. Olcen

Parizeau was employed in support of scientific and hydrographic programs, Ocean and Aquatic Sciences, Tides and Currents, Ocean Chemistry, Ocean Ecology, Offshore Oceanography, Loran "C" calibration; Pacific Geoscience Centre Geology; Department of National Defence, Ocean Acoustics; University of British Columbia, Oceanography.

CSS *WM. J. STEWART* (65 m, 1920 tonnes)

Decommissioned and scheduled for disposal.

CSS *VECTOR* (39.6 m, 505 tonnes)

Master: J.C. Marston

Chief Engineer: J.J. Peat

Vector carried out programs in support of Coastal Zone Oceanography, Ocean Chemistry, Offshore Oceanography, Ocean Ecology; Pacific Environmental Institute, Biology; Environmental Protection Service; University of British Columbia, Oceanography; Simon Fraser University, Oceanography.

CSS *RICHARDSON* (19.8 m, 78 tonnes)

Master: M.G. Wheeler

Chief Engineer: I.N. Henderson

Richardson continued sidescan sonar programs with Pacific Geoscience Centre, oceanographic survey with Ocean Chemistry, oceanographic survey with U.B.C., search and rescue duties, and fishery patrol duties.

M.V. *RADIUM EXPRESS* (22.2 m, 100 tonnes) on charter

Master: Wm. Kirkland

Chief Engineer: F. Bogart

Continued Mackenzie River and Mackenzie Bay hydrographic surveys.

M.V. *PANDORA II* (58.2 m, 1220 tonnes) on charter

Master: R.A. Jones

Chief Engineer: C. Tuck

I.A. Sturgess

Pandora II with *Pisces IV* were employed in the following programs: for Ocean and Aquatic Sciences, Ocean Mixing and Ocean Ecology; for Defence Research Establishment Pacific, Acoustic and Flow Noise trials; for Environmental Protection Service, examination of mine dumpsites; and for Pacific Geoscience Centre, Geology off the northwest coast of Vancouver Island; *Pandora II* herself conducted three months of hydrographic survey in the Amundsen Gulf.

PISCES IV (6.1 m, 12 tonnes)

Chief Pilot: I. Sanderson

Pisces IV, a deep diving submersible, was engaged in a geological survey of the Continental Shelf, investigation of ocean mixing at the edge of the Fraser River plume, investigation of mine tailings for the Environmental Protection Service, recovery of tidal survey meters and pilot training. She is scheduled for major modification early in 1979.

CSL *REVISOR* (11 m, 10 tonnes)

The launch *Revisor* was used in support of coastal oceanographic programs and acoustic experiments.

LAUNCHES

Survey launches were employed by shore-based hydrographic parties working in the Strait of Georgia, Alberni Inlet and the Mackenzie River.

DEPOT

The depot workshops continue to provide full support to all Institute activities.

MANAGEMENT SERVICES DIVISION

N. A. Todd - Chief of Management Services

Todd, N.A. - Chief of Division

Aanhout, D.L. van - Secretary, Regional Hydrographer

*Clarke, B.E. - Secretary, F.S.R.G., Coastal and Offshore Oceanography

Coldwell, J.H. - Stores

Cotter, M.L.

Craton, M.I.K.

Crouch, R.W. - Purchasing

Curtis, J.N.

Deane, G.J.

Doyle, D.A. - Secretary, Regional Marine Superintendent

Drysdale, A.E.

Hall, E.J.

Harbar, M.S.

Jones, K.M.G. - Secretary, Chief, Management Services

*Kwiatkowski, B.S.

Lapp, B.I.

Lohrmann, B.A. - Administrative Services

Mathias, A.L. - Secretary, Ocean Chemistry

McKenzie, S.D. - Secretary, Regional Oceanographer

Miles, M.L.

Parsons, J.E. - Finance

Peirson, E. - Secretary, F.S.R.G., Coastal and Offshore Oceanography

*Powers, M.A. - Secretary, Ocean Chemistry

*Raine, G.M. - Secretary, F.S.R.G., Coastal and Offshore Oceanography

Reinstein, H.G. - Facilities Operation and Maintenance

Sabourin, J.T.

Smith, R.M.

Thomas, C.D. - Central Registry

van Dusen, T.S. - Secretary, Director-General

*Left during 1978

Commissionaires

Sgt. D.W. Price	Comm. E. Hawkings
Sgt. W.L. Caldwell	Comm. H. Moffat
Comm. G. Bradshaw	Comm. A. Samouelle
Comm. J. Gessner	Comm. C. Taylor
Comm. G. Glass	Comm. L. Trerice

Institute of Ocean Sciences - Construction

The long awaited occasion when all units forming the Institute of Ocean Sciences came together on one site occurred early in 1978.

Ocean Chemistry moved into their new wing in January and quickly became operational. With this move all of the premises at Harbour Road in Victoria were vacated. These premises are now being used by the Ministry of Transport.

The Department of Energy, Mines and Resources occupied their new offices and laboratories during the early spring months. Units of the Earth Physics Branch and the Geological Survey of Canada are located in the Institute and collectively are now known as the Pacific Geoscience Centre.

With the exception of a very few contracts, all construction work has now been completed. CANA Construction, who acted as Construction Managers for the project, turned over the management of the outstanding work to the Department of Public Works in June. A large part of the work since this date has been concerned with clearing up deficiencies and having corrective action taken under warranty.

Our experience so far indicates that the original design concepts inherent in the architectural brief have been satisfactorily realized and the physical facilities and layout are conducive to the achievement of our program objectives.

The large number of people visiting and touring the Institute during 1978 (approximately 2100 took conducted tours) indicates that the public is highly interested in the work being carried out at the Institute. It was also reassuring to hear many complimentary expressions from the local public on the presence of the Institute and its perceived significance, regionally and nationally.

Administration

The anticipated increased workload of getting the new facilities "on line" and of operating and maintaining them became a reality in 1978. At times it became almost the normal state to perform in a reactive mode to crisis situations. By and large, the staff was able to overcome these situations; and with some indication that we may be able to achieve a better balance between workload and resources we look forward to being able to operate in 1979 in a more even manner.

The financial, purchasing and materiel management, records management and administrative support components all felt the pressures of meeting increasing demands on them. These demands increased due to the general climate in government of greater administrative control, to implementing the terms of our cost-sharing agreement with the Pacific Geoscience Centre, to two full audits -- one by the Auditor General and one by Audit Services Bureau -- and to some extent with the setting up of the new Department of Fisheries and Oceans. The latter may bring some relief as it appears the regional administrative offices will be allocated some manyears for 1979.

Further refinements were made in our Financial and our Manyear Reporting Systems and continued progress was made with the Inventory System. A Safety Committee has been organized and is functioning.

Changes in staff have perhaps been a little higher than normal. This was to be expected as staff adjusted to the change in the location.

Director General's Office

For the purposes of financial administration the Office of the Director General comes under Management Services. In an agency where the operational demands of scientists and hydrographers are naturally paramount, and administrative support staff are viewed as not always necessary evils, one welcomes opportunities to report on the scientific activities of members of one's group -- in this case the Director General.

In this last year Dr. Stewart not only had his usual clutch of book reviews, referee's reports, editor's remarks and research grant referrals to deal with, but he wrote a sizeable article on "Ocean Currents" for MacMillan's Merit Students Encyclopedia, one for the fall '78 issue of Oceanus on "The Role of Sea Ice and Climate" and one for Atmosphere-Ocean on "The Oceans, the Climate and People - With a View from Mars". In addition, he has finally completed a small book for the World Meteorological Organization on the Atmospheric Boundary Layer.

It is difficult to fit these activities into the performance measurement indicators being used within Management Services. They identify more closely with the performance review and evaluation exercise of science and service activities that was conducted on a more rigorous level in 1978 than previously as part of the annual review and planning process. The pressures of inflation and government constraint combined with growing demands for Institute research and survey services continue to increase the administrative workload on the Director General's office. The staff position, Program Analysis and Liaison, has greatly assisted in offsetting this situation.

LIBRARY

S. Thomson - Librarian

C. Firth - Library Clerk

Nineteen seventy-eight was a year of expansion for the Library with the Earth Physics Branch of the Department of Energy, Mines and Resources adding their 20-year accumulation of geophysics materials to the existing Library collection. Our holdings increased by at least 30% and some of the long runs of bound journals proved most welcome to many users. The Geological Survey of Canada (DEMR) enhanced the journal subscription list by 20 titles but have not yet contributed to the monograph collection. There were noticeable increases in borrowings, on-line searches and reference requests -- all welcome. We look forward in 1979 to functioning as a fully integrated library service serving all Institute needs.

TASK FORCE, COMMITTEE AND SIMILAR ACTIVITIES

DIRECTOR-GENERAL'S OFFICE

Stewart, R.W.

Joint Organizing Committee (JOC) of the Global Atmospheric Research Program (GARP)

Canadian National Scientific Committee for GARP

Scientific Committee on Oceanic Research (SCOR) - member executive committee

SCOR - IAMAP - IAPSO Working Group on Air-Sea Interaction Research (COSPAR) - Canadian delegate

Sea Use Council (Canada-USA) - vice-chairman

Regional Board, Pacific Region (DOE)

Regional Board, Western and Northern (DOE)

National Research Council of Canada - GARP Grants Advisory Committee

Physical Oceanographic Commission (IAPSO) - President

Arctic Environmental Steering Committee

Arctic Waters Oil and Gas Advisory Committee

Royal Society of Canada Interdisciplinary Selection Committee

Vancouver International Airport Panel Member

American Meteorological Society - Councillor

Cornford, A.B.

Working Committee for Global Investigations of Pollution in the Marine Environment (GIPME)

HYDROGRAPHIC DIVISION

Ages, A.B.

Environmental Emergency Working Group, Victoria Zone

Navigational Relative Risk Index Sub-group

Technical Committee (DOE), Annacis Island Sewage Treatment

Bolton, M.

Hydrographic Committee CIS
National Cartographic Appraisal Board
National Hydrographic Survey Officers' Appraisal Board
National Hydrographic Training Committee
New Research/Survey Vessel Users Design Committee - Chairman
Pacific Sub-Committee on Oceanography of CCO - MEMBER
Research Ship Scheduling Committee
Joint DOE/DEMR Guiding Committee of Offshore Surveys
International Hydrographic Technical Conference - chairman

Curran, T.A.

Electronics Technology Program Advisory Committee, Camosun College

Galloway, J.L.

Steering Committee for the Establishment of International Shipboard
Data Acquisition Standards

Huggett, W.S.

New Research/Survey Vessel Users Design Committee
Environmental Emergency Working Group, Victoria Zone

O'Connor, A.D.

Canadian Institute of Surveying, Victoria Branch - past chairman

Rapatz, W.J.

B.C. Civil Defense Tsunami Committee
Ocean Dumping Act - inspector

Sandilands, R.W.

Hydrographic Technical Committee, Canadian Institute of Surveying
The Canadian Surveyor - associate editor (hydrography)
Lighthouse - Canadian Hydrographers Association - assistant editor
Survey Technology Advisory Committee - Camosun College
Workshop Group on Offshore Surveys for Mineral Resource Development
Board of Trustees, Maritime Museum of B.C.
International Hydrographic Technical Conference Committee (1979)
Canadian Institute of Surveying, Victoria Branch, Vice-chairman
Canadian Hydrographers Association, Pacific Region - Executive Member

Smithers, F.R.

Public Information Group, DOE Pacific
Regional Committee on Interagency Routing of Navigational Information
Advisory Board, Camosun College

Smith, A.

Sub-committee of CPCGN for Undersea features
(Canadian Permanent Committee Geographical Names)

Watt, J.V.

Electronics Technology Program Advisory Committee, Camosun College

Wills, R.

Regional Hydrographic Survey Officers' Appraisal Board - chairman
Regional Committee on Interagency Routing of Navigational Information
Survey Technology Advisory Committee, BCIT
Regional Board, Pacific Region, Estuary Working Group

Wigen, S.O.

International Co-ordination Group for the Tsunami Warning System in the
Pacific - National Representative
Canadian Working Group on the Use of Satellites in the Tsunami Warning
System - Chairman
Joint Federal/Provincial Tsunami Working Group - Chairman

OCEAN CHEMISTRY DIVISION

Cretney, W.J.

Laboratory Safety Committee, Ocean Chemistry - Chairman
Institute Safety Committee
Institute Cafeteria Committee

Macdonald, R.W.

Ocean Dumping Technical Committee, Pacific Region

Thompson, J.A.J.

Institute Safety Committee
Laboratory Safety Committee, Ocean Chemistry
Pacific Nuclear Activation Research Association - Secretary

Wong, C.S.

Environmental Contaminant Act Advisory Committee, Pacific Region
NRC Associate Committee on Marine Analytical Standards, Atlantic
Regional Laboratory

OCEAN ECOLOGY LABORATORY

Brinkhurst, R.O.

Hon. Prof. - University of Victoria
Research Associate - Royal Ontario Museum
Visiting Professor - College of Marine Sciences, University of Delaware
Regional Ocean Dumping Advisory Committee - OAS Representative
CCREM Shoreline Management Conference - OAS Delegate
Standards Council of Canada - Delegate International Conference
Standards Council of Canada - ISO/TC/147/Sc5 member
Chairman - A.S.L.O. local organization committee, 1978 meetings
Chairman - First International Aquatic Oligochaete Biology Symposium/
International Assn. of Theor. and Applied Limnology
Graduate Student Committees - University of Victoria (3) UNB (1)
Science Subvention Programme Review Committee - Regional OAS Representative
Fellow, Rawson Foundation
Advisor, North Saanich Municipal Council (Environment)
Guest lecturer, University of Toronto (dedication of A.G. Huntsman library)
ASLO Winter 1978 (symposium speaker)
Nominee - President, N. American Benthological Assn. (President)
- Am. Soc. Limnol. Oceanogr. (member at large)

Denman, K.L.

A.S.L.O. Symposium Chairman
A.S.L.O. Organizing Committee member
Can. Meteorological and Oceanographic Society citations committee chairman

Gardner, G.

A.S.L.O. Organizing Committee (Secretary)

Mackas, D.

A.S.L.O. Organizing Committee (Posters)

OCEAN PHYSICS DIVISION

Farmer, D.M.

Babine Lake Steering Committee

American Geophysical Union, Estuarine and Coastal Oceanography Committee

Garrett, J.F.

Canadian National Committee for SCOR

Committee of Participants for the Drifting Buoy System for the FGGE
(Chairman)

Subgroup of Experts on Products and Services of IGOSS for the FGGE

Giovando, L.F.

Joint Working Committee Lower Fraser River Environmental Monitoring

B.C. Coastal Zone Resource Subcommittee

Roberts Bank Environmental Subcommittee

Gower, J.F.R.

Canadian Advisory Committee on Remote Sensing, Working Group on
Oceanography - Chairman

National Research Council Associate Committee on Space Research

NASA SEASAT Synthetic Aperture Radar Experiment Team - associate member

DOE Committee on Remote Sensing

Lewis, E.L.

UNESCO/SCOR/IAPSO/ICES Joint Panel of Experts on Oceanographic Tables
and Standards (SCOR W.G. 10)

SCOR/IAPSO Working Group 51 - Evaluation of CTD Data

SCOR Working Group 58 - Arctic Ocean Heat Budget

Canadian Committee on Oceanography Panel on Ice - Arctic Oceanography
Subcommittee

Marine Science Communications - Editorial Advisory Board

Canadian National Committee for SCOR

Milne, A.R.

Arctic Marine Oilspill Program Advisory; Committee member

Arctic Islands Pipeline Project Studies; Board member

Polar Gas Pipeline Project; EARP panel member

Arctic Region Ocean Dumping Advisory Committee member

Canadian Advisory Committee on Remote Sensing, Working Group on Ice

Beaufort Sea Contingency Planning Task Force; Scientific Advisor

Beaufort Sea Scientific Response Plan; Coordinator

Arctic Petroleum Operators Association/Federal Govt. Steering Committee
for Research on Offshore Problems

Miyake, M.

Canadian GARP Scientific Committee

Executive Committee Mixed Layer Experiment, U.S. Office of Naval Research

Associate Editor "Boundary Layer Meteorology"

Honorary Associate Professor - Institute of Oceanography, Univ. of B.C.

SCOR WG 47 - FEGG - Oceanography Pacific

Murty, T.S.

Tsunami Committee of International Union of Geodesy and Geophysics -
Vice-chairman

Canadian Meteorological and Oceanographic Society - Recording Secretary

Organizing Committee of Symposium on St. Lawrence Estuary held at
University of Quebec in April '78

Organizing Committee of Symposium on long waves in the ocean held at
Ottawa in June '78

Nasmyth, P.W.

Canadian National Committee for SCOR

Joint Group of Experts for IGOSS - Subject Leader

PhD. supervisory committee for Andre Langlais - UVic (Chemistry)

IOS Library Committee (Chairman)

Smiley, B.D.

Fate and Effects Working Group of Advisory Group on Research and
Development and Member (EPS-AGRAD) Petrocan Environmental Advisory
Committee; member

Tabata, S.

Ocean Climate Panel of Working Group 48 of the Scientific Committee on
Oceanic Research (SCOR)

Canadian Committee on the Proposed Formation of ICES of the Pacific
(International Council for Scientific Investigation of the North Pacific)

Organizing Committee of the 13th Canadian Meteorological and
Oceanographic Congress (Canadian Meteorological and Oceanographic Society)

Thomson, R.E.

RSCC Task Force on the proposed Floating Dry Dock, Burrard Inlet
Associate Editor, Atmosphere and Oceans
Treasurer, XIII Congress CMOS

COMPUTING SERVICES

Teng, K.

West Coast Electronic Data Processing Coordinating Committee; DFE
Organizing Committee for CIPS/ACM Northwest '78 Regional Computer
Conference. General Co-Chairman

Johns, R.E.

West Coast Electronic Data Processing Coordinating Committee, DFE
Canadian Information Processing Society, Victoria Section, Treasurer

INDUSTRIAL LIAISON AND CONTRACT ACTIVITY

Smith, G.R.

Advisory Board on Marine Technology, B.C. Research

SHIP DIVISION

Geldart, E.N.

Pacific Regional Resource/Survey Vessel Committee - secretary

* * * * *

SCIENCE RELATED CONTRACTS AWARDED IN 1978

Numerical modelling study of the movement of Fraser River discharge in the Southern Strait of Georgia, Part II University of B.C., Vancouver, B.C.	2,000
Study of the effects of dumping dredge spills containing wood debris on benthic communities in Port Alberni, B.C. Dobrocky Seatech Ltd., Victoria, B.C.	2,000
Development of software for random access memory system (RAMS) buoy data A.S. Thorndike, Seattle, Washington USA	254

Preparation of check standards, calibration graphs and other procedures for chemical analysis of water samples L. Barry, Victoria, B.C.	11,500
Software development and modification of existing programs of portable hydrographic acquisition systems (PHAS) Multilek Incorporated, Ottawa, Ontario	4,500
Collating and plotting of oceanographic data C. Wallace, Sidney, B.C.	3,290
Development of computer programs for hydraulic research CPRO Computing Enterprises Incorporated, Victoria, B.C.	23,748
Development of computer programs for numerical modelling. Nawitka Renewable Resource Consultants Ltd., Ladysmith, B.C.	4,095
Development of computer programs for remote sensing Apocalypse Enterprises Incorporated, Victoria, B.C.	15,998
Development of computer programs for Ocean Mixing Apocalypse Enterprises Incorporated, Victoria, B.C.	17,581
Development of a microprocessor Based, precision Acoustic Navigation System for surveying from a small submersible Mesotech Systems Ltd., North Vancouver, B.C.	227,000
Oceanic water properties sampling and measurement program aboard the weathership CCGS <i>Quadra</i> Seakem Oceanography Ltd., Sidney, B.C.	55,000
Provision of support to the Institute of Ocean Sciences to carry out oceanographic programs Bastion City Charters, Nanaimo, B.C.	21,258
Development of computer programs for numerical modelling Dobrocky Seatech Ltd., Victoria, B.C.	19,910
Collection and analysis of data on the spatial distribution of plankton in B.C. coastal waters G.C. Louttit, Sidney, B.C.	10,595
Laboratory study of behaviour of oil and gas particles in salt water relating to deep oil well blowouts University of Calgary, Calgary, Alberta	52,557
Sediment and oligochaete sample collection from the Fraser River P. Chapman, Victoria, B.C.	1,450
Documentation of oceanographic station data E. Wong, Victoria, B.C.	1,460
Oceanographic support to Institute of Ocean Sciences Dobrocky Seatech Ltd., Victoria, B.C.	20,000

Study on the behaviour, pathways residence time and toxicity of polychlorinated biphenyls (PCB) in the marine environment Seakem Oceanography Ltd., Sidney, B.C.	25,000
Analysis of the behaviour, pathways, residence time and toxicity of tetraethyl lead in the marine environment Seakem Oceanography Ltd., Sidney, B.C.	25,000
Hydrocarbon baseline study of Kitimat Harbour, Douglas Channel and approaches Seakem Oceanography Ltd., Sidney, B.C.	281,797
Analysis of B.C. coastal water data from the Department of Fisheries and Environment color spectrometer Seakem Oceanography Ltd., Sidney, B.C.	7,000
Biological oceanographic research support to the Institute of Ocean Sciences University of Victoria, Victoria, B.C.	7,500
Marine biological sampling and observations of temporal changes in benthic communities and benthic respiration at a dumpsite in Port Alberni Dobrocky Seatech Ltd., Victoria, B.C.	29,010
Collection and supply of hydrographic field data for correction and up-dating navigational charts and sailing directions I.J. Campbell, Sidney, B.C.	16,486
Analysis of oceanographic data collected in Queen Charlotte Sound, Hecate Strait and Johnstone Strait B. Choo, Victoria, B.C.	6,090
Deployment of controlled ecosystem enclosures J & J Divers, Victoria, B.C.	800
Deep water blowout trajectory models for the Lancaster Sound Region Arctic Sciences Ltd., Sidney, B.C.	23,859
Numerical modelling studies of the estuarine circulation in the Strait of Georgia system, Part I University of B.C., Vancouver, B.C.	10,000
Support for the West Coast Ocean Dumping Program Dobrocky Seatech Ltd., Victoria, B.C.	7,214
Examination of boundary conditions for linearized shallow water equations F. Milinazzo, Victoria, B.C.	2,000
Examination of evidence for an internal tide in Alberni Inlet Seakem Oceanography Ltd., Sidney, B.C.	4,402

Provision of oceanographic support for a surface current study in Juan de Fuca Strait Ivanhoe Enterprises, Vancouver, B.C.	7,344
Development of a meaningful criteria for ocean disposal of dredged or sedimentary material, Part II Seakem Oceanography Ltd., Sidney, B.C.	10,241
Development of a meaningful criteria for ocean disposal of dredged or sedimentary material, part I Can Test Ltd., Vancouver, B.C.	10,421
Study on the methylation of arsenic in marine sediments and interstitial waters in Rupert Inlet, B.C. Beak Consultants Ltd., Vancouver, B.C.	11,738
Oceanographic observations aboard CCGS <i>Quadra</i> T. Juhasz, Victoria, B.C.	6,512
Development and testing of moorings for use in areas of negligible horizontal magnetic fields, Phase I Dobrocky Seatech Ltd., Victoria, B.C.	21,201
Deployment of moorings in areas of negligible horizontal magnetic fields, Phase II Dobrocky Seatech Ltd., Victoria, B.C.	12,528
Analysis of phytoplankton primary productivity samples from the B.C. Continental Shelf J.R. Forbes, Ladysmith, B.C.	480
Modifications to the software of the multi-probe data acquisition system Apocalypse Enterprises Inc., Victoria, B.C.	5,000
Identification and sorting of B.C. marine zooplankton samples W. Carolsfeld, Victoria, B.C.	4,770
Identification and sorting of B.C. marine zooplankton samples H.A. Sefton, Victoria, B.C.	4,770
Documentation of oceanographic data from the ice drift buoy program S. Hill, Victoria, B.C.	3,000
Processing of physical oceanographic data as returned by oceanographic observers from the weather ship <i>Quadra</i> and <i>Vancouver</i> Interact Computing Services Ltd., Victoria, B.C.	3,381
Feasibility study using ships of opportunity to collect physical and biological oceanographic data Seakem Oceanography Ltd., Sidney, B.C.	130,485

Modifications to the Dept. of Fisheries and Environment submersible <i>Pisces IV</i> to permit safe operation in deep ocean areas International Hydrodynamics Ltd., Vancouver, B.C.	262,473
Determination of the lead methylating capacity of Pacific coastal marine sediments Beak Consultants Ltd., Vancouver, B.C.	7,358
Examination of the variability of upwelling on the West Coast of Vancouver Island and its relationship to the flushing of Alberni Inlet Beak Consultants Ltd., Vancouver, B.C.	7,980
Analysis of sediment samples for polychlorinated biphenyls Seakem Oceanography Ltd., Sidney, B.C.	6,300
A physical oceanographic study in the Kitimat Area (Amendment) Dobrocky Seatech Ltd., Victoria, B.C.	152,225
Research on the methylation of arsenic in marine sediments and interstitial waters in Rupert Inlet, B.C. Beak Consultants, Vancouver, B.C.	9,650
Analysis of plankton samples from B.C. coastal waters G. Gardner, Brentwood Bay, B.C.	9,500
Investigation of tubificid oligochaete niches and their role in mobilization of some heavy metals in lake sediments Beak Consultants Ltd., Mississauga, Ontario	32,795
Historical examination of tide graphs for evidence of tsunamis and tabulation of results M. Lane, Victoria, B.C.	1,000
Analysis of samples of marine lolothurian, molpadia intermedia for determination of copper, zinc and cadmium Can Test Ltd., Vancouver, B.C.	1,377
Development of software routine for translating and calibrating sea data tape reader output Interact Computing Services Ltd., Victoria, B.C.	2,050
Provide descriptions of B.C. Marine Oligochaetes H.R. Baker, Victoria, B.C.	2,300
Hydrocarbon determination in seawater Seakem Oceanography Ltd., Sidney, B.C.	28,500
Laboratory study of behaviour of oil and gas particles in salt water relating to deep oil well blowouts University of Calgary, Calgary, Alberta	55,000

PUBLICATIONS

Institute of Ocean Sciences, Patricia Bay, 1978 Annual Report

PACIFIC MARINE SCIENCE REPORTS

PMSR 78-1

Offshore Oceanography Group

Oceanographic observations at Ocean Station P -
29 July - 14 September 1977. Volume 84,

PMSR 78-2

Giovando, L.F.

Observations of seawater temperature and
salinity at British Columbia shore stations
1974.

PMSR 78-3

Tabata, S.

An examination of the quality of sea-surface
temperatures and salinities observed recently
in the northeast Pacific Ocean.

PMSR 78-4

Herlinveaux, R.H., D.B. Fissel &
S.E.G. Wilson

Oceanographic observations in Barrow Strait
and Wellington Channel, N.W.T. April 1973.

PMSR 78-5

Wigen, Sydney O.

Historical study of tsunamis - an outline.

PMSR 78-6

Foreman, M.G.G.

Manual for tidal currents analysis and
prediction.

PMSR 78-7

Offshore Oceanography Group

Oceanographic observations along Line P and
off the coast of British Columbia 19 August -
10 September, 1975.

PMSR 78-8

Giovando, L.F.

Observations of seawater temperature and
salinity at British Columbia shore stations
1975.

PMSR 78-9

Brinkhurst, R.O. (Ed.)

Report on ocean dumping R and D Pacific Region
Fisheries and Environment Canada 1976-1977.

PMSR 78-10

Macdonald, R.W., M.E. McFarland, Oceanographic data report Amundsen Gulf
S.J. De Mora, D.M. Macdonald & August-September 1977.
W.K. Johnson

PMSR 78-11

Thompson, J.A.J. & D.W. Paton Heavy metals in benthic organisms from Point
Grey dumpsite - Vancouver, B.C. - A
preliminary report.

PMSR 78-12

Giovando, L.F. Observations of seawater temperature and
salinity at British Columbia shore stations
1976.

PMSR 78-13

Mortimer, A., D.H. Gray & A Loran-C calibration, the West Canadian
R.M. Eaton Chain offshore operations and data analysis.

PMSR 78-14

Seakem Oceanography Ltd. Oceanographic observations at Ocean Station P -
9 September - 26 October 1977. Volume 85.

PMSR 78-15

Seakem Oceanography Ltd. Oceanographic observations at Ocean Station P -
17 October - 7 December 1977. Volume 86.

PMSR 78-16

Seakem Oceanography Ltd. Oceanographic observations at Ocean Station P -
2 December 1977 - 11 January 1978. Volume 87.

PMSR 78-17

Mortimer, A., D.H. Gray & A Loran-C calibration, the West Canadian Chain
R.M. Eaton inshore operation and data analysis.

PMSR 78-18

Seakem Oceanography Ltd. Oceanographic observations at Ocean Station P -
6 January - 15 February 1978. Volume 88.

PMSR 78-19

Seakem Oceanography Ltd. Oceanographic observations at Ocean Station P -
10 February - 29 March 1978. Volume 89.

PMSR 78-20

Seakem Oceanography Ltd. Oceanographic observations at Ocean Station P -
24 March - 10 May 1978. Volume 90.

PMSR 78-21

Hill, S.H., D.B. Fissel &
H. Serson

A study of wind and atmospheric pressure in
Eastern Parry Channel, N.W.T. - Summer, 1977.

PMSR 78-22

Mortimer, A., R.M. Eaton &
D. Gray

A Loran-C calibration, West Canadian Chain
synchronized time of arrival measurements.

PMSR 78-23

Greisman, Paul and Robert
A. Lake

Current observations in the channels of the
Canadian Arctic Archipelago adjacent to
Bathurst Island.

PMSR 78-24

Macdonald, R.W., D.M. Macdonald
and P.S. Munro

Oceanographic data report Kitimat Arm,
Porpoise Harbour February 1977.

PMSR 78-25

Watt, John V.

Extending the bathymetric capability of the
M.V. Pandora II.

PMSR 78-26

Hill, S.H.

A guide to the effects of underwater shock
waves on arctic marine mammals and fish.

PMSR 78-27

Seakem Oceanography Ltd.

Oceanographic observations at Ocean Station P -
5 May - 21 June 1978. Volume 91.

PMSR 78-28

Gower, J.F.R., ed.

Passive radiometry of the ocean.

CONTRACTOR REPORT SERIES

CRS 78-1

Fissel, D.B., Arctic Sciences,
Ltd.

Measurements of the direction sensitivity of
three current meters as a function of magnetic
field intensity.

CRS 78-2

MacNeill, M.R., B.R. de Lange
Boom and D. Ramsden, Seakem
Oceanography, Ltd.

Radar tracking of ice in the Griffith Island
area of Barrow Strait, N.W.T.

CRS 78-3

Fissel, D.B. and G.R. Wilton,
Arctic Sciences Ltd.

Subsurface current measurements in Eastern
Lancaster Sound, N.W.T. - Summer 1977.

CRS 78-4

Fissel, D.B. & J.R. Marko,
Arctic Sciences Ltd.

A surface current study of Eastern Parry
Channel, N.W.T., Summer 1977.

CRS 78-5

Marko, J.R., Arctic Sciences
Ltd.

A satellite imagery study of Eastern Parry
Sound.

OTHER PUBLICATIONS - 1978

- Aubin, F., T.S. Murty and M.I. Eb-Sabh. 1978. Numerical simulation of the movement and dispersion of oil slicks in the upper St. Lawrence estuary, preliminary results. *Le Naturalist Canadien*. (in press)
- Brinkhurst, R.O. 1978. Freshwater Oligochaeta in Canada. *Can. J. Zool.* 56: 2166-2175.
- Corneil, D.G. & M.E. Woodward, 1978. A comparison and evaluation of graph theoretical clustering Techniques. *INFOR*, Vol. 16, No. 1, pp. 74-89.
- Crean, P.B. 1978. A numerical model of barotropic mixed tides between Vancouver Island and the mainland and its relation to studies of the estuarine circulation. *Hydrodynamics of Estuaries and Fjords. Proceedings of 9th Colloquium of Ocean Hydrodynamics*. Amsterdam, Elsevier pp. 283-314.
- Cretney, W.J., C.S. Wong, D.R. Green and C.A. Bawden, 1978. Long-term fate of a heavy fuel oil in a spill-contaminated B.C. coastal bay. *J. Fish. Res. Bd. Can.*, 35(5), 521-527.
- Denman, K.L. and A.W. Herman, 1978. Space-time structure of a continental shelf ecosystem measured by a towed porpoising vehicle. *J. Mar. Res.* 36: 693-714.
- Denman, K.L. and D.L. Mackas, 1978. Collection and analysis of underway data and related physical measurements. In: *Spatial Pattern in Plankton Communities*. Editor, John H. Steele, Plenum Publishing, New York.
- Eaton, R.M., A.R. Mortimer and D.H. Gray. Accurate Chart Latticing for Loran C. *Lighthouse, Sp. Ed.*, April 1978. pp. 11-17.

- Farmer, D.M. & J.D. Smith, 1978. Nonlinear internal waves in a fjord.
In: Hydrodynamics of Estuaries and Fjords: Proceedings of the 9th
Liege Colloquium on Ocean Hydrodynamics. Amsterdam, Elsevier
pp. 465-495.
- Farmer, D.M., 1978. Observations of long nonlinear internal waves in a lake.
J. Phys. Oceanog. 8: 63-73.
- Freeland, H.J., 1978. (Coauthor in the Mode Group) The Mid-Ocean Dynamics
Experiment. Deep Sea Research 25(10), 859-910.
- Gargett, A.E., 1978. Microstructure and fine structure in an upper ocean
frontal regime. J. of Geophysical Res. 82(C10), 5123-5134.
- Gower, J.F.R. & B. M. Oliver, 1978. Observations of coastal water surface
currents using an airborne inertial sighting system. J. Geophys.
Res. 83, 1941-1946.
- Irwin, B., W.G. Harrison, K.L. Denman & T. Platt, 1978. Phytoplankton pro-
ductivity and nutrient measurements at the edge of the continental
shelf off Nova Scotia, between April 29 and May 11, 1977. Fish.Mar.
Service Data Rept. No.62, 90p.
- Kremling, K., J. Piuze, K. von Bruckel, & C.S. Wong, 1978. Studies on the
pathways and effects of cadmium in controlled ecosystem enclosures.
Marine Biology, 48, 1-10.
- Levesque, L., M.I. El-Sabh & T.S. Murty. 1978. Movement des l'eaux induit
par la Maree et le vent dans l'estuaire du St. Laurent. Le
Naturalist Canadien. (In press).
- Levesque, L., T.S. Murty & M.I. El-Sabh. 1978. Numerical modelling of tidal
propagation in the St. Lawrence estuary. International
Hydrographic Bulletin. (In press).
- Lewis, E.L. and R.G. Perkin. 1978. Salinity: Its definition and Calculation.
J. Geophys. Res. Vol. 83, pp. 466-478.
- Lewis, E.L. and R.B. Sudar. 1978. A salinity chain for estuarine use.
Oceans '78. Inst. Electrical & Electronic Engineers Inc., New
York. Publ. #78, CH, 0134-7, OEC.
- Luternauer, J.L., R.H. Linden and R.E. Thomson. 1978. Applications of side-
scan sonar to Geoenvironmental Research in the coastal waters
of British Columbia, Scientific and Technical Notes in Current
Research, Part B, Geol. Surv. Can. pp.181-186.
- Melling, H. & R. List. 1978. Acoustic Doppler sounding of falling snow.
J. Appl. Meteor. 17: 1267-1273.
- Melling, H. & R. List. 1978. Doppler velocity extraction from atmospheric
acoustic echoes using a zero-crossing technique, J. Appl. Meteor.
17: 1274-1285.

- Milne, A.R. and B.D. Smiley. 1978. Offshore Drilling in Lancaster Sound. Possible Environmental Hazards. Sidney, Institute of Ocean Sciences, Patricia Bay. 98 pp.
- Milne, A.R. 1978. Oil, Ice and Climate Change. The Beaufort Sea and the search for oil. Beaufort Sea Overview Report. Sidney, Beaufort Sea Project. 103 pp.
- Mortimer, A.R., R.M. Eaton and D.H. Gray. 1978. Calibration of the West Canadian Loran C Chain. Canadian Aeronautics and Space Journal. Vol. 24, No.3, pp. 129-135.
- Murty, T.S. & R.J. Polavarapu. 1978. Influence of an ice layer on the propagation of long waves. Marine Geodesy. (In press).
- Murty, T.S. 1978. Moving boundary problems - discontinuous flows - catastrophe theory and numerical modelling. In: Computing methods in Geophysical Mechanics. New York, American Society of Civil Engineers. pp. 79-92.
- Murty, T.S. 1978. Submarine land-slide generated water waves in Kitimat Inlet, B.C. Proc. of the 25th Annual Meeting of the Pacific Northwest Region of the American Geophysical Union. (In press).
- Murty, T.S. 1978. Tsunami generation by meteorite impacts. Proceedings of the Long Wave Symposium. Edited by G. Godin, Ocean and Aquatic Sciences, Fisheries and Environment Canada, Ottawa. (In press).
- Nasmyth, P.W. 1978. Instruments and Methods in Air-Sea Interaction, Techniques of Measurement from Towed Vehicles and Submersibles, Presented at NATO Advanced Study Institute on Instruments and Methods in Air-Sea Interaction, Norway, April. 30 pp. (In press)
- Perkin, R.G. and E.L. Lewis. 1978. Mixing in an arctic fjord. J. Phys. Oceanography, Vol. 8, pp. 873-880.
- Riser, S.C., H.J. Freeland and H.T. Rossby, 1978. Mesoscale motions near the deep western boundary of the North Atlantic. Deep Sea Research 25(12).
- Sandilands, R.W. 1978. Captain James Cook. R.N., Hydrographer. The Canadian Surveyor, (in press).
- Stewart, R.W., 1977. Oil and the Ocean, Proceedings of the World Conference Towards a Plan of Actions for Mankind. Vol. 2 pp. 119-122.
- Stewart, R.W., 1978. The Oceans, the Climate and People (with a view from Mars). Atmosphere-Ocean 16(4), 367-376.
- Stewart, R.W., 1978. Ocean Variability - The Influence of Atmosphere Processes. Advances in Oceanography, 213-219 pp.

- Stewart, R.W., 1978. The Role of Sea Ice in Climate. *Oceanus*. 21(4): 47-57.
- Stronach, J.A. & P.B. Crean. 1978. Upper Layer, Strait of Georgia Data Report 1975-1976. Institute of Oceanography, University of B.C. Data Report #44. 284 pp.
- Tabata, S. 1978. Comparison of observations of sea surface temperatures at Ocean Station P and NOAA buoy stations and those made by merchant ships travelling in their vicinities, in the northeast Pacific Ocean. *J. Applied Meteorology*, 17(3): 374-385.
- Tabata, S. 1978. An evaluation of the quality of sea surface temperatures and salinities measured at Station P and Line P in the northeast Pacific Ocean. *J. Phys. Oceanogr.* 8(6): 970-986.
- Tabata, S. 1978. On the accuracy of sea-surface temperatures and salinities observed in the northeast Pacific Ocean. *Atmosphere-Ocean* 16(3): 237-247.
- Thomson, R.E. and J.L. Luternauer, 1978. The tidal regime and sedimentation patterns in Johnstone Strait British Columbia, *Scient. and Tech. notes in Current Res.*, Part A, *Geol. Surv. Can.*
- Wigen, S.O. 1978. Canada's Role in the International Tsunami Warning System. *Proceedings of the 17th Annual Canadian Hydrographic Conference*. Lighthouse, Special Edition, pp. 18-24.
- Wigen, S.O. 1978. Some Developments and Applications in Tsunami Research. *Proceedings of International Symposium on Long Waves in the Ocean*. Ottawa, Marine Sciences Directorate, Manuscript Report Series. (In press).
- Wong, C.S. 1978. Carbon dioxide -- a global environmental problem into the future. *Marine Pollution Bulletin*, Vol. 9, No. 10.
- Woodward, M., 1978. Measurement of currents in narrow passes using in situ pressure gauges. *Proceedings of the 17th Annual Canadian Hydrographic Conference*. Lighthouse, Special Edition, pp. 43-50.
- Yorath, C.J., B.D. Bornhold and R.E. Thomson. 1979. Oscillation megaripples on the northeast Pacific Continental Shelf, *J. Marine Geology*, (in press).

PERMANENT STAFF 1978

DIRECTOR GENERAL

Stewart, R.W.; B.Sc., M.Sc., (Queen's), Ph.D. (Cantab), FRSC, FRS,
D.Sc. (McGill), LL.D. (Dalhousie).

ASSISTANT TO DIRECTOR GENERAL

Cornford, A.B.; B.Sc. (McMaster), Ph.D. (Brit.Col.)

MANAGEMENT SERVICES DIVISION

Todd, N.A.; B.S. (Glasgow), M.A. (Carleton) - Chief of Division

Aanhout, D.L. van	Lohrmann, B.A.; B.Sc., M.Sc. (Guelph)
*Clarke, B.E.	Mathias, B.
Coldwell, J.H.	McKenzie, S.D.
Cotter, M.L.	Miles, M.L.
Craton, M.I.K.	Parsons, J.E.
Crouch, R.W.	Peirson, E.
Curtis, J.N.	*Powers, M.A.
Deane, G.J.	*Raine, G.M.
Doyle, D.A.	Reinstein, H.G.
Drysdale, A.E.	Sabourin, J.T.
Firth, C.	Smith, R.M.
Hall, E.J.	Thomas, C.D.
Harbar, M.S.	Thomson, L.S.C.; B.A. (Saskatchewan)
Jones, K.M.G.	B.L.S. (Brit.Col.)
*Kwiatkowski, B.S.	van Dusen, T.S.
Lapp, B.I.; B.A. (Victoria)	

COMPUTING SERVICES

Butcher, J.W.; B.Sc. (Victoria), M.Sc. (Toronto)	Page, J.S.; B.Sc. (Brit.Col.)
Douglas, A.N.; B.Sc. (Victoria)	Richards, P.J.; B.Sc. (Brit.Col.)
Foreman, M.G.; B.Sc. (Queen's), M.Sc. (Victoria)	Smith, D.B.; B.Sc. (Victoria)
Johns, R.E.; B.Sc. (Victoria), M.Sc. (Brit.Col.)	Teng, K.; B.A.Sc., M.A. (Brit.Col.)
Oraas, S.R.; B.A.Sc., M.A.Sc. (Brit.Col.)	Wharton, A.H.; B.Sc. (Victoria)
	Woollard, A.L.; B.Sc. (Victoria)
	*Woodward, M.E.; B.Sc. (Victoria)
	M.Sc. (Toronto)

* Left during 1978

HYDROGRAPHIC DIVISION

Bolton, M. - Regional Hydrographer

- | | |
|---|---|
| Ages, A.B.; B.A.Sc., M.A.Sc.
(Brit.Col.), P.Eng. | Ma, A.C.; B.Sc. (Victoria) |
| Bell, R.D. | *Manley, A.B.; Dip. BCIT |
| Brown, R.E. | *Manson, J. |
| Browning, P.C. | May, R.I.D.; Dip. BCIT |
| *Carracedo, C. | Milner, P.R.; Dip. BCIT |
| Chan, G.L. | Moody, A.E. |
| *Chivas, J.W.; Master, F.G. | Mortimer, A.R.; Master, F.G., B.Sc.
(Victoria) |
| *Clark, D.J. | Morton, P.A.; A.O.C.A. |
| Coldham, F.A. | Muse, R.A.; Trade Cert.CAF |
| Crawford, W.R.; B.Sc., M.A.Sc.
(Waterloo), Ph.D. (Brit.Col.) | *Narayanan, K. |
| Crowley, J.V. | Nielson, G.C. |
| Crowther, W.S. | O'Connor, A.D.; Master, H.T.(U.K.),
350 T |
| Curran, T.A.; B.A.Sc. (EE)
(Brit.Col.), P.Eng. | Osborne, M. |
| Czotter, K.L.; Dip. BCIT | Parker, R.N.S. |
| D'Aoust, A.J. | Patton, M.M. |
| Dobson, D.C. | Philp, A.R. |
| Dorosh, L.W.; Dip. BCIT | Pickell, L.M. |
| Earl, E.L.P. | Pierce, R.A. |
| Eaton, G.H.; Dip. BCIT | Popejoy, R.D. |
| Ellison, G. | Preece, M.L.; Dip. BCIT |
| Farmer, M. | Rapatz, W.J.; B.Sc. (Victoria) |
| Fisher, D.L. | Raymond, A.R.; Dip. (Algonquin College) |
| Galloway, J.L.; B.A.Sc. (EE)
M.A.Sc.(EE) (Brit.Col.), P.Eng. | Richardson, G.E. |
| Gould, J. | Ross, A.D. |
| Gregson, D.J.; Dip. BCIT | Said, N.A. |
| Harris, W.J. | Sandilands, R.W.; Ltd.(H) RN (Ret'd.) |
| Harrison, D. | Sargent, E.D.; Dip. BCIT |
| Hermiston, F.V. | Schoenrank, R.U.; B.Sc. (Victoria) |
| Hinds, E.W.; Dip. BCIT | Smedley, A.J.; Lcdr.RCN (Ret'd.) |
| Hohl, M. | Smith, A.; Master F.G. |
| Hollinger, C.; Dip. BCIT | Smith, G.R.; B.A.Sc.(ME)
(Brit.Col.), P.Eng. |
| Holman, K.R. | *Smithers, F.R. |
| Huggett, S. | Steeple, J.; Cert.Mech.Eng.
(Edinburgh) |
| Huggett, W.S.; Master, F.G. | St. Gelais, J. |
| Johnson, B.A.; Dip. BCIT | Stephenson, F.E.; B.Sc. (Victoria) |
| Josephson, K.G. | Tamasi, C.R.; Dip. BCIT |
| Korhonen, R.K. | *Taylor, M.S. |
| Kynoch, B.D. | Taylor, R.G. |
| Larkin, J.G.; B.Sc. (P.E.I.) | Taylor, W.R.; Dip. RCC |
| Loschiavo, R.; Dip. BCIT | Thompson, L.G. |
| Lusk, B.M.; Master, 350 T | Van Duen, W.P.; Dip. BCIT |
| Lyon, A.G. | Vosburgh, J.A.; Dip. BCIT |
| *Lyons, W.J.L.; C.C. (Ont. Inst.
Cartographers) | Wakefield, L.M. |
| | Ward, M.M.; Dip. BCIT, B.A. (Geog.) |

*Left during 1978

Watt, B.M.
Watt, J.W.; B.A.Sc.(EE) (Brit.Col.),
P.Eng.
Whincup, G.
Wigen, S.O.; B.A.Sc. (Brit.Col.),
P.Eng.
Wills, R.; Master, F.G.

Wood, D.J.; Dip. BCIT
Woods, M.V.; Dip. BCIT
Woodward, M.J.; B.Sc. (Victoria,
M.Sc. (Toronto)

OCEAN PHYSICS DIVISION

Nasmyth, P.W.; B.A.Sc., M.A., Ph.D. (Brit.Col.) - Chief of Division

Bell, W.H.; B.A.Sc. (Brit.Col.),
M.Sc. (Hawaii), P.Eng.
Bigham, R.H.
Chase, G.W.; Dip. BCIT
Cooke, R.A.
Crean, P.B.; B.Sc. (Dublin),
M.A.Sc. (Toronto), Ph.D.
(Liverpool)
de Jong, C.
Farmer, D.M.; B.Com., M.Sc. (McGill),
Ph.D. (Brit.Col.)
Freeland, H.J.; B.A. (Essex),
Ph.D. (Dalhousie)
Gargett, A.E.; B.Sc. (Manitoba),
Ph.D. (Brit.Col.)
Garrett, J.F.; B.A. (Harvard),
Ph.D. (Brit.Col.)
Giovando, L.F.; B.A., M.A., Ph.D.
(Brit.Col.)
Gower, J.F.R.; B.A., M.A., Ph.D.
(Cantab)
Henry, R.F.; B.Sc. (Edinburgh),
Ph.D. (Cantab)
Herlinveaux, R.H.
Kamitakahara, G.R.; B.Sc. (Toronto)
Koppel, A.W.
Kimber, P.M.
Kuwahara, L.S.C.; B.Sc. (Brit.Col.)
Lake, R.A.; B.Sc. (Brit.Col.),
M.Sc. (Washington)
Lewis, E.L.; B.Sc., M.Sc., Ph.D.
(London)

Linguanti, J.
Love, J.
McNeill, J.M.
Meikle, J.H.
Milne, A.R.; B.A.Sc. (Toronto),
M.Sc. (McGill)
Minkley, B.G.; Dip. BCIT
Miyake, M.; B.S.(EE) (Drexel), M.S.,
Ph.D. (Washington)
Moorhouse, S.W.
Murty, T.S.; B.Sc. (Andhra), M.Sc.
(Andhra), M.S. (Chicago),
Ph.D. (Chicago)
Perkin, R.G.; B.A.Sc., M.Sc. (Brit.Col.)
Richards, D.L.
Sieberg, D.G.; Dip. VVI
Smiley, B.D.; B.Sc., M.Sc. (Alberta)
Spearing, L.A.F.; B.Sc. (Brit.Col.)
Stickland, J.A.
Stucchi, D.J.; B.A.Sc. (York),
M.Sc. (Dalhousie)
Sudar, R.B.; B.A.Sc. (Toronto)
Tabata, S.; B.A., M.A. (Brit.Col.),
D.Sc. (Tokyo)
Teichrob, R.C.; Dip. BCIT
Thomson, R.E.; B.Sc., Ph.D. (Brit.Col.)
*Walker, E.R.; B.Sc. (Manitoba),
M.A. (Toronto), Ph.D. (McGill)
Wallace, J.S.

OCEAN ECOLOGY LABORATORY

Brinkhurst, R.O.; D.Sc. (London) - Head

Austin, M.J.; B.Sc. (Brit.Col.)
Denman, K.L.; B.Sc. (Calgary), Ph.D.
(Brit.Col.)

*Left during 1978

OCEAN CHEMISTRY DIVISION

Wong, C.S.; B.Sc., M.Sc. (Hong Kong), Ph.D. (Scripps), Dip. Mar. Sc. (UNESCO)
MCIC, FRIC - Chief of Division

Bellegay, R.D.; Dip. NAIT, Ass. Deg. in Oceanography (Shoreline Community College, Seattle)	McLaughlin, F.; B.Sc. (Victoria)
Cretney, W.J.; B.Sc., Ph.D. (Brit.Col.)	Munro, P.; B.Sc. (Queen's)
Johnson, W.K.; Dip. BCIT	Paton, D.; B.Sc. (Brit.Col.)
Macdonald, D.M.; B.A.Sc. (Brit.Col.)	Soutar, T.J.; Dip. BCIT
Macdonald, R.W.; B.Sc., Ph.D. (Dalhousie)	Thompson, J.A.J.; B.Sc. (McMaster), Ph.D. (Alberta)

SHIP DIVISION

Geldart, E.N.	1st Class Marine Engineer, Fellow Institute of Marine Engineers; Regional Marine Superintendent
*Green, F.S.	Master Mariner; Assistant Marine Superintendent (Deck)
Norton, N.St.C.	Master F.G.; Assistant Marine Superintendent (Deck)
Parkinson, R.W.	Engineer 1st Class Combined; Chief Engineer
*Keene, R.W.	Master, F.G. (X); Relief Master
Henderson, J.D.	Engineer 2nd Class Steam; Depot Supervisor
*Chan, C.C.	Engineer 1st Class Motor; Relief Engineer
Redman, D.J.	

CSS *PARIZEAU*

Chamberlain, A.G.	Master, F.G.; Master
Fisher, E.G.	Master, F.G.; 1st Officer
Christie, J.N.	Radio Certificate; W/O
Clarke, L.E.	Supply Officer
*Kyle, R.G.	Engineer 2nd Class Motor; Senior Engineer
Olcen, P.	Engineer 1st Class Motor
*Orr-Hood, J.	Engineer 4th Class Motor; 2nd Engineer

CSS *WM. J. STEWART*

Sjoholm, K.J.	Master, F.G.; Master <i>Vector</i>
*Easson, R.J.	Master, F.G.; 1st Officer
Palmer, S.	Supply Officer (<i>Parizeau</i>)
Gibson, R.G.	Engineer 3rd Class Steam; Senior Engineer, Relief Engineer
Conway, A.	Engineer 4th Class Combined; 2nd Engineer <i>Vector</i>

* Left in 1978

CSS *VECTOR*

*Marston, J.C.	Master, F.G.; Master
Bishop, S.O.	Master H.T.; 1st Officer, Relief Chief Officer
Price, G.	Mate, H.T.; 2nd Officer
*Purdon, D.	Mate, H.T.; 2nd Officer
Peet, J.	Engineer 3rd Class Motor; Chief Engineer <i>Vector</i>
Pearson, R.	Engineer 3rd Class Motor; 1st Engineer <i>Vector</i>
*Knoblauch, I.	Engineer 4th Class Motor; 2nd Engineer

CSS *RICHARDSON*

Wheeler, M.G.	Master, M.T.; Master
Henderson, J.N.	Engineer 4th Class Motor; Chief Engineer

MV RADIUM EXPRESS

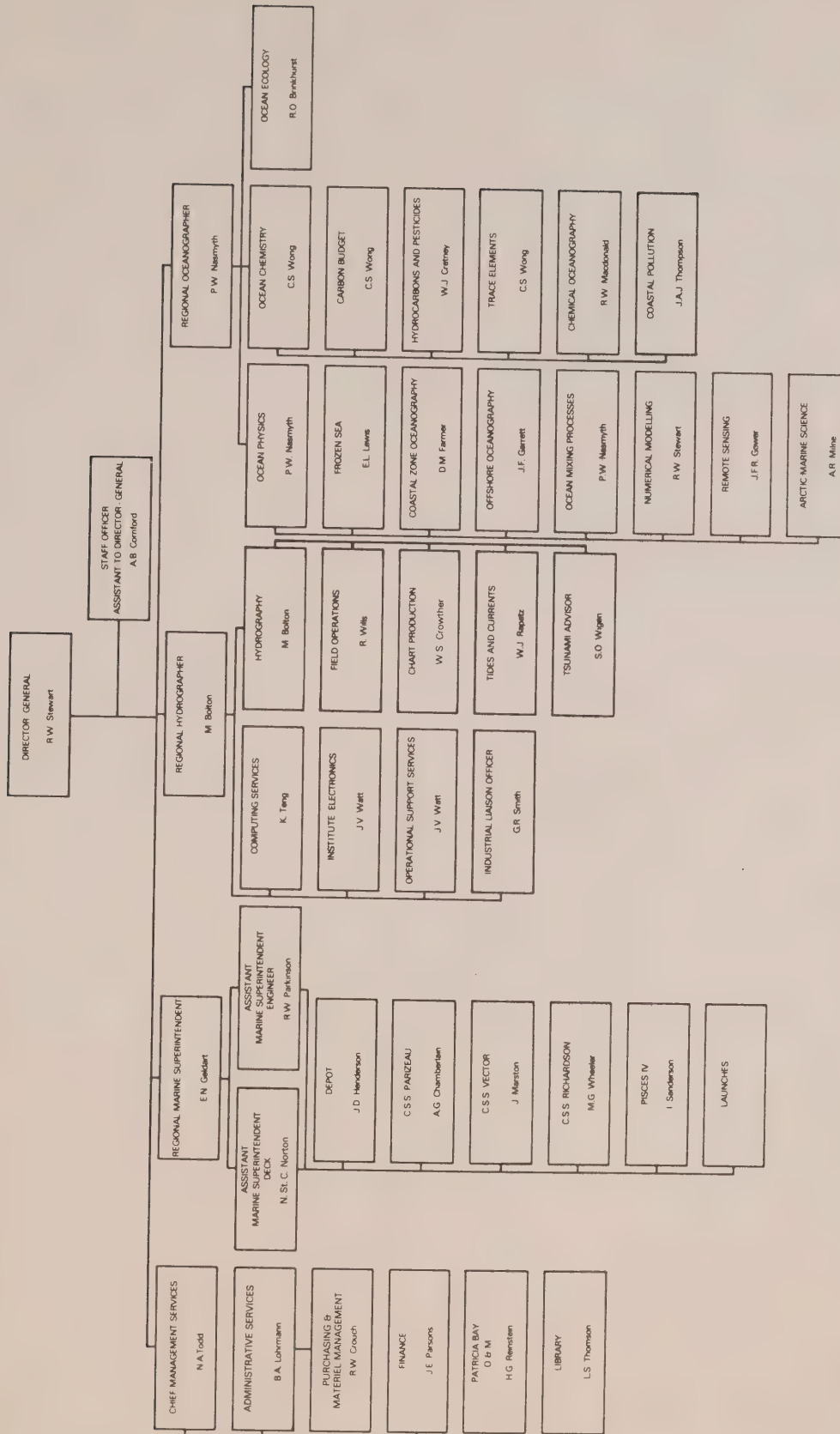
O'Sullivan, J.	Master
Butler, W.	Chief Engineer

MV PANDORA II (Charter)

Jones, R.	Master
*Tuck, C.	Chief Engineer
Newton, J.	Chief Engineer

PISCES IV

Sanderson, I.	Chief Pilot
Chambers, F.	Pilot
Taylor, R.H.	Pilot
Jacobson, R.	Pilot
*Gaudreault, J.	Pilot
Grant, D.	Pilot
Manion, G.W.	Pilot



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INSTITUTE OF OCEAN SCIENCES, PATRICIA BAY

ANNUAL REPORT — 1979

**INSTITUTE OF OCEAN SCIENCES
Sidney, B.C.**



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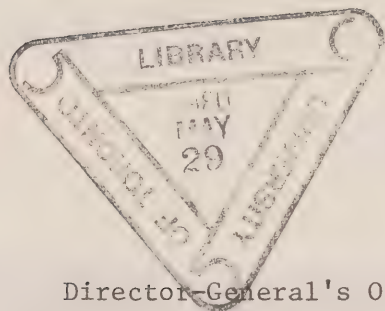
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V8L 4B2

INSTITUTE OF OCEAN SCIENCES, PATRICIA BAY
ANNUAL REPORT 1979



Sidney, B.C.

March, 1980



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DIRECTOR-GENERAL'S OFFICE

C.R. MANN

T. Van Dusen - Secretary

*A.B. Cornford - Head, Program Analysis
and Liaison

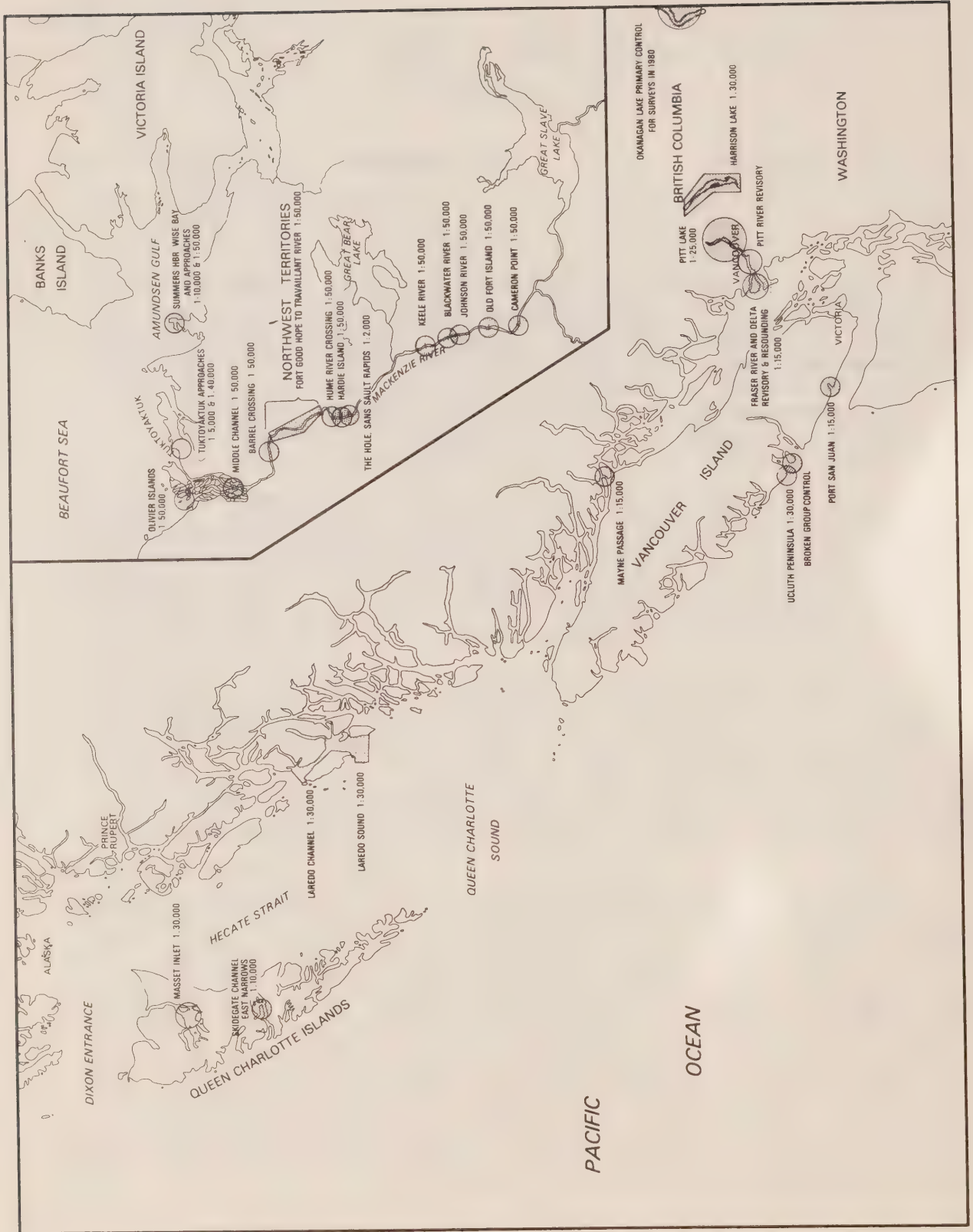
1979 is the second year that members of the Institute of Ocean Sciences have occupied the new building at Patricia Bay. It has been a year during which the various groups have developed a spirit of togetherness in their diverse endeavours, as distinct from their rather isolated existence before they were housed in the same building. The Institute was formally opened by the Governor General, His Excellency the Right Honourable R. E. Schreyer on February 28, 1979. A picture of Mr. Schreyer with Dr. R. W. Stewart on his left forms our title page.

Several changes in our senior staff have taken place. Dr. Stewart left on executive exchange with the Province of British Columbia in mid-year. He was replaced by Dr. C. R. Mann who transferred from our sister institute, the Bedford Institute of Oceanography on the east coast. Dr. P. W. Nasmyth, the Regional Oceanographer, retired in June, and Mr. R. W. Sandilands was appointed Regional Field Superintendent in the Hydrographic Division.

As usual fiscal restraints are still with us; we lost one half of our capital budget for this year, but the difficulties imposed upon us have been offset by the enthusiasm of our staff in developing the hydrographic and oceanographic programs. There is a great deal of work that needs to be done off our west coast and in the western Arctic. It will all get done, eventually, but only at the pace we can set with our present resources. I doubt it will be fast enough to meet the burgeoning commercial developments.

Two developments that augur well for the future are the signing of an agreement between the Federal Government and the Provincial Government of British Columbia for the lease of land opposite the Institute to develop a Marine Technology Centre devoted to the development of marine industry, and the move by OAS at the national level to research and produce papers on marine transportation in the Arctic, ocean climate, and on other subjects of national interest. The inauguration of the Centre follows many years of assistance in the development of Marine Industry by IOS through contracts, and the DSS unsolicited proposal route in support of the government's Make-or-Buy policy. If it develops as it should, the Centre will greatly strengthen the marine sciences on the west coast. Perhaps with the presentation of well-thought out papers on marine science we can obtain the resources we need to meet the growing demand for marine research.

*Acting Regional Oceanographer - July-December 1979



HYDROGRAPHIC DIVISION

M. Bolton - Regional Hydrographer

S. B. McKenzie - Secretary

The year's activities were predicated, to a large extent, by the governmental climate of fiscal restraint. The reduction in the available operational and capital resources combined with reduced purchasing power of the dollar resulted in an inevitable restriction of field activities. This was particularly noticeable in the Arctic, where the high cost of operations and logistic support precluded the mounting of a major field program. Nonetheless, significant work was accomplished in various areas of the region.

The high priority assigned to the completion of surveys in the Beaufort Sea has been reflected in several ways. Studies have been contracted to examine methods for detection of many pingo-like shoals in the area. Short and long term planning for future major survey programs in cooperation with the oil industry have been undertaken. Internal and external negotiations for logistic support for Arctic programs is continuing.

Miscellaneous programs for various agencies involved considerable time and effort. The Canadian Coast Guard Vessel Traffic Management Radar Monitoring System was calibrated. Displays and tours were designed for the Canadian Power Squadrons. Specific surveys were undertaken at the behest of the Pacific Pilotage Authority, Canadian Coast Guard, and the British Columbia tourist industry. A map and brochure showing the federal fishing and recreational harbours was produced for the small Craft Harbours Branch. Positioning equipment and personnel were provided for the DEMR gravity and magnetic survey of Hecate Strait.

A major internal program involved the Tidal and Current Survey section which devoted considerable time, personnel and resources to the Coastal Ocean Dynamics Experiment, in close cooperation with the Offshore Oceanography section. A high level of support was provided to all elements of the Institute by Computing Services and Engineering Services.

Personnel changes saw the retirement of Ralph Wills after 25 years of service and the appointment of R. W. Sandilands to replace Mr. Wills as Regional Field Superintendent. W. J. Rapatz was confirmed in the position of Regional Tidal Superintendent and K. R. Holman was appointed Production Chief in the Chart Production and Distribution Section.

FIELD HYDROGRAPHY SECTION

Regional Field Superintendent - R. Wills*
 - R.W. Sandilands***

F.A. Coldham	M.L. Preece
J.V. Crowley	A.R. Raymond
K.L. Czotter	G.E. Richardson
G.H. Eaton	E.D. Sargent
B.M. Lusk	R.U. Schoenrank
R.I.D. May	C.R. Tamasia
P.R. Milner	W.P. Van Duin
A.R. Mortimer	J.A. Vosburgh
A.D. O'Connor	M.M. Ward
R.D. Popejoy	D.J. Wood
	M.V. Woods

Head, Sailing Directions R.W. Sandilands until 12 November
 Acting Head, Sailing Directions A. Smith from 13 November
 L.M. Wakefield

Head, Hydrographic Development J.B. Larkin
 A.J. D'Aoust
 **R.I.D. May
 **P.R. Milner

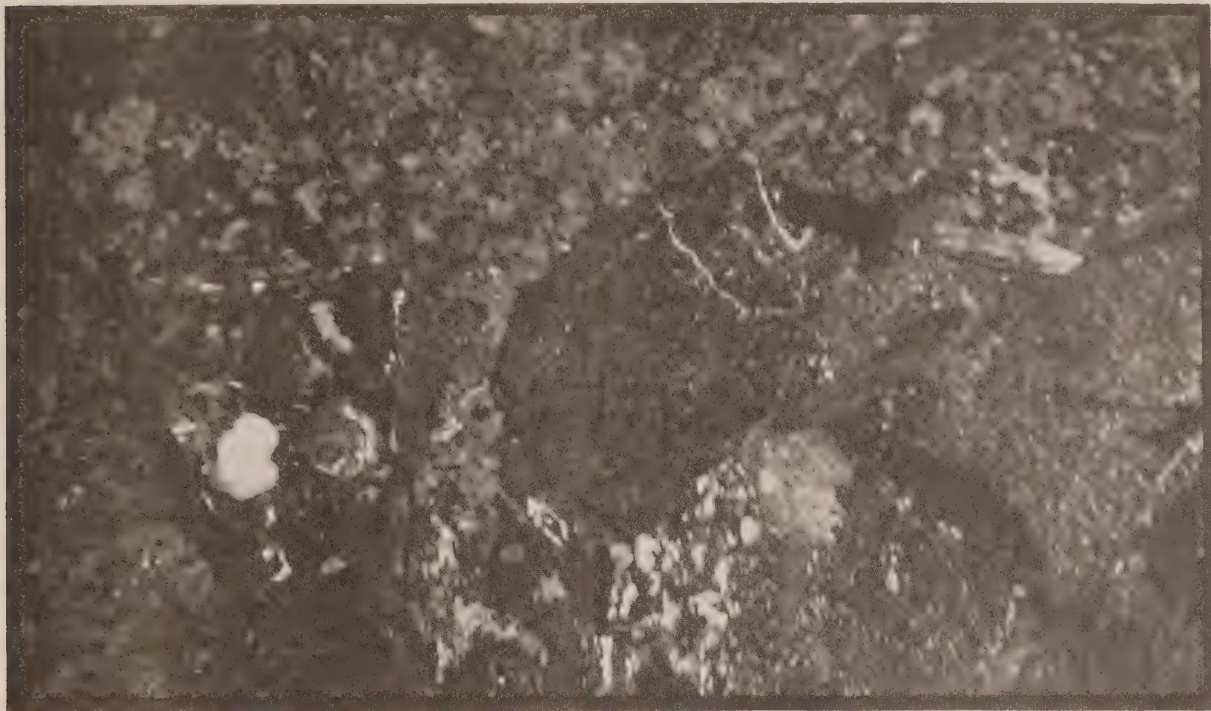
*Left during 1979
 **Rotational Staff in Hydrographic Development
 ***Promoted

The main hydrographic work on the B.C. coast in 1979 was carried out by a large party with Mr. Lusk in charge. Operations commenced in April with surveys of Harrison Lake and River which are previously unsurveyed highly used recreational areas. The main lake was completed by the end of May and work on the river was suspended on 8 June to allow the party time to transfer to CSS *Parizeau* for the major coastal survey of the season, a resurvey of Laredo Sound and Channel.

On 14 June *Parizeau* sailed for survey. Participating in this survey for experience were Mr. Sander, an instructor in surveying at Camosun College, Victoria and Mr. Idigo, a surveying student from Nigeria. The area was complex and over four hundred shoals were examined, several of these being known shoals which were, on examination, found to have less water over them than charted. Notice to Shipping and to Mariners action was taken. The survey was completed on 23 August.

The rationale for these surveys was the provision of modern charting for the deep-draught ore carriers en route to Kitimat. One of these carriers hit an obstruction in Laredo Sound in the vicinity of Wilson Rock in early November. A small party, including divers, under the charge of Mr. Lusk and accompanied by a Department of Transport Investigating Officer embarked on

CSS *Vector* and returned to the area. After positioning themselves over a reported shoal in the vicinity of the position claimed by the pilot the divers went down and found portions of the ship's bottom and other evidence to confirm that the ship had indeed struck a reported shoal.



Broken pieces of rock in the vicinity of the grounding



The diver's knife is pointing to a large piece of metal off the ship's hull

The survey of Harrison River was recommenced on 4 September and was completed by 13 September. A subparty then travelled to the Okanagan Lake to carry out some preliminary work for the 1980 field season. This party completed operations at the end of September.

The second B.C. coastal survey party was conducted on CSS *Richardson*, with Mr. Vosburgh in charge. They commenced the season with a resurvey of Mayne Passage between east and west Thurlow Islands. Next they surveyed Port San Juan, previously surveyed in 1932, and this was followed by completion of work started in 1978 on the outer coast of the Ucluth Peninsula. While in this area some preliminary survey control was established in the Broken Group in Barkley Sound. In July the party moved to the Queen Charlotte Islands where Skidegate Narrows and its ranges were surveyed. The remainder of the season was spent in Masset Inlet where a resurvey was completed before the party returned to Sidney on 23 September.

A shore party under Mr. Richardson divided its activities between the B.C. Coast and the Western Arctic. It started the season with a resurvey of selected sections of the Fraser River delta. These were areas previously sounded in 1974 and the object of the work was to duplicate those surveys and thus provide sedimentologists of the Geological Survey of Canada with an on-going record of changes in the delta. A survey of Pitt Lake was completed in May and June and in July the party went north for two months. On its return south in September the Fraser River delta survey was completed and revisory work done in the Fraser River, Pitt River and Lake and in Vancouver Harbour.

The projected cruise of *Pandora II* to the Western Arctic was cancelled for reasons of financial restraint and so surveys in that area were minimal this year. With support from the Canadian Coast Guard and Canmar, the shore party was able to complete surveys of Wise Bay and Summers Bay together with their approaches. A detailed survey of the approach channel to Tuktoyaktuk was also completed.

The M/V *Radium Express*, on charter from Northern Transportation Company Ltd. (NTCL), continued the Mackenzie River survey with Mr. Crowley as Hydrographer-in-Charge. The program concentrated on the lower portion of the river below Fort Good Hope although several short stretches upstream from there were sounded. The most recent buoy and range positions were fixed for the total length of the Mackenzie River. Since 1972, hydrographic surveys of the Mackenzie system have been conducted annually using the NTCL charter vessel *Radium Express* but, in view of current restraints and CHS national priorities, the project has been terminated.

Surveillance of the artificial islands in the Beaufort Sea was continued with a set of photographs being taken in August.

The Navigation Group headed by Mr. Mortimer undertook several projects during the year. One of the major ones included an investigation of low frequency navigation systems coverage in the Western Arctic and the implementation of the BIONAV integrated satellite navigation system onboard CSS *Parizeau*. The new Loran C transmitter at Port Hardy was positioned and support was given for projects carried out by other disciplines at the Institute and the Pacific Geoscience Centre (PGC).

In November, a small hydrographic field party provided assistance to the Ministry of Transport in calibrating the Mount Newton radar monitor which is an integral part of the Vessel Traffic Management system, Vancouver Traffic Control Centre.

Eleven staff from hydrography attended the International Hydrographic Technical Conference held in Ottawa in May and two of these, Mr. Bolton, Chairman and Mr. Sandilands, Publications, were active on the organizing committee for this, the first such technical conference.

The Region hosted the field training portion of the Hydrography I course and provided HQ staff with additional training support.

Sailing Directions

The Sailing Directions Section revises and maintains two volumes of Sailing Directions and two volumes of Small Craft Guides. New editions of these volumes are published on a two year cyclical basis.

The fourth edition of B.C. Small Craft Guide, Volume I, Vancouver Island, Port Alberni to Campbell River including the Gulf Islands, was published in May. This publication continues to be very popular with the recreational sailor with sales of over twelve hundred in the first eleven months of the year.

The eleventh edition of B.C. Sailing Directions (South Portion), Volume I was received from the printer in December.

Sailing Directions for Kootenay Lake and River, Chart 3050, a strip chart in book format which includes Directions, were amended to include new information gathered during a field revisory survey. These Directions were passed to the Chart Compilation Section for chart production action.

New editions of B.C. Sailing Directions (North Portion), Volume II and B.C. Small Craft Guide, Volume II, Boundary Bay to Cortes Island, are under preparation for publication in the 1980/81 fiscal year.

The section participated in a revisory survey contract during the year and the only field work carried out involved helicopter flights to obtain new photography for Small Craft Guide, Volume I.

Hydrographic Development

Mr. D'Aoust has been seconded to Canada Centre for Remote Sensing, in Ottawa, to work full time on the Aerial Hydrography Project. The contract with P.A. Lapp, Ltd. is proceeding on schedule, with a flight test being conducted during the summer in the Thousand Islands area of the St. Lawrence River. Mr. D'Aoust is the scientific authority for the contract, and is also involved with improvements to the track recovery system using previous data obtained by flying over an accurate test range in Arizona. Results of

test flights conducted to date are promising, and indicate the possibility of Arctic production flights in 1981.

Hydrographers R. May and P. Milner joined the group for their rotational assignment.

It was intended to carry out field trials of NAVBOX units but due to manufacturing delays the units were not available, and trials have been postponed until next year.

Mr. Milner familiarized himself with the Kongsberg flatbed plotter, and assisted field parties in preparation of field sheet base plots and survey lattices.

Mr. Milner also made a field trip to the Western Arctic with A.R. Mortimer conducting Loran C monitor tests, and later assisted with the data reduction.

CHART PRODUCTION AND DISTRIBUTION SECTION

W.S. Crowther - Regional Chart Superintendent

R. Bell - Supervisor New Chart Production	A. Lyon
P. Browning - Navigational Aids	*M. Mikkelsen
G. Chan	**P. Morton
D. Dobson - Nautical Information	**G. Neilson
E. Earl	**R. Parker
M. Farmer	M. Patton
D. Fisher - Supervisor Chart Sales	A. Philp
J. Gould	L. Pickell
D. Harrison - Supervisor Chart Correction	R. Pierce
M. Hohl	A. Ross - Quality Control
K. Holman - Production Chief	N. Said
**S. Huggett	**J. St. Gelais
K. Josephson	R. Taylor
*B. Kenny	L. Thompson - Quality Control
R. Korhonen	B. Watt
D. Kynoch	G. Whincup

* Joined during 1979

** Left during 1979

Chart Production

The main effort of the Chart Production Section in 1979 was chart maintenance. New Chart production was impeded by the resignation of three cartographers and the transfer of one other to the Atlantic Region. One cartographer attended the Cartography I course at Headquarters.

Despite setbacks because of limited resources, accomplishments in chart production must be considered successful. One specific highlight in New Charts was the commencement of production for 3311, a Small-craft strip chart of the Sunshine Coast.

The relocation of Chart Distribution and Chart Correction activities away from Chart Production, and the subsequent relocation of the Technical Records Unit adjacent to the production units has helped to make regular activities more efficient.

A new Ozalid machine was purchased and installed in the Photo-Mechanical Unit. The relocation of the venting system contributed to a more efficient and reliable reproduction capability. A small contact frame was received and is being installed, permitting the simultaneous processing (contacting) of very small and very large copy at any given time without interference.

There were a number of non-charting activities undertaken during 1979. The largest undertaking in this area was the Small-craft Harbour map for Small Craft Harbours Branch which includes a comprehensive facilities listing. About 450 other miscellaneous projects were undertaken for all units of the Institute. They ranged from half-hour photographic jobs to forty-hour drafting projects.

The number of requests for information and copies of survey documents from the private sector continues to grow. An average of eight telephone queries are handled daily by our Nautical Information Officer.

The rotation of senior cartographers into the Quality Control Unit continued through most of 1979 whereby working level cartographers spent two-month periods on assignment. This has given participants an opportunity to demonstrate their ability and management an opportunity to assess their capabilities.

Chart Production hosted a number of tours for individuals and groups directly associated with chart-making. The largest of these groups consisted of 125 members of the Victoria Canadian Power Squadron. A second Canadian Power Squadron (CPS) tour for the Brentwood Squadron turned out about 50 members. Also, a total of three displays were prepared including the CPS Display which will be made available on loan to CPS Squadrons across Canada.

As usual, distribution of charts reached its peak in mid-summer. Delays due to volume in mid-summer were as high as ten days but complaints regarding delays were at a minimum. Chart Distribution embarked on an advertising program which began with the circulation of two Newsletters to all Chart Dealers in the Region. Efforts are being made to maintain closer contact with Dealers, thereby improving the service to chart users.

In Automated Cartography the following graphics are now being generated on the Univac 1106 computer and drawn on the Kongsberg flatbed plotter:

1. fully graduated borders, international style;
2. small-craft borders;
3. hyperbolic navigational lattices, including Loran-C;
4. wind velocity charts;
5. grids.

Cartographers in Chart Production are now being trained in the use of these programs and are using them in the production of charts. Cartographers are also using a GOMADS program to produce borders for compartment charts and for charts with insets. The MOSAIC program is now operational but has not yet been used in production. This program generates source file data at varying scales and produces projections to a common file.



Chart Production and Distribution personnel including summer students photographed on one of several terraces at the Institute of Ocean Sciences. June 1979.

The digitizing program was received from Ottawa and was modified to handle the Talos digitizing table and to run under the RSX11M operating system. Also, the Talos system had the following modifications:

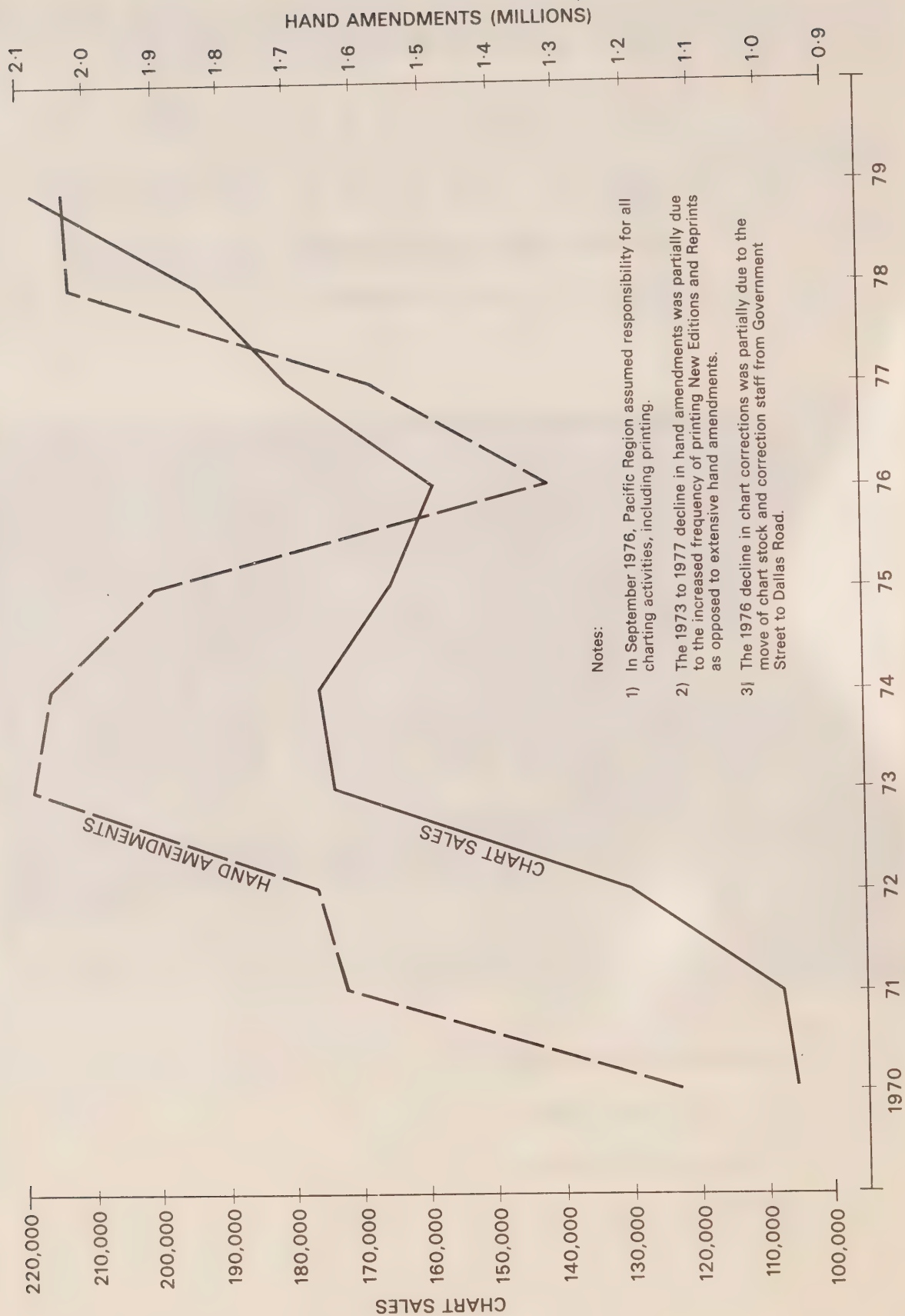
1. the interface was modified to give the system the same functional capabilities as the Gradicon table;
2. a beeper/talk box was designed and built by Institute Electronics;
3. a scribing cursor was designed and built by contract.

The digitizing table had unacceptably large errors and was sent back to the factory for repairs.

Production & Distribution Statistics 1979

New charts published	6
New editions published	61
Preprints published	16
Overprinting of existing chart stocks	1
Notices to Mariners	107
Notices to Shipping processed	13
Chart patches printed	6
Number of charts corrected	197,500
Chart corrections (hand amendments)	2,158,317
Total charts distributed	224,110
Total publications distributed	74,073
Dealerships inspected	36
New dealerships established	20
New Small-craft dealers	15
Dealerships withdrawn	5
MAREPS processed	306

Pacific Region : Chart Sales & Hand Amendments



TIDAL AND CURRENT SURVEY SECTION

W.J. Rapatz - Regional Tidal Superintendent

A.B. Ages - i/c Hydraulic Research
 R.E. Brown
 W.R. Crawford - i/c Tidal Research
 A.N. Douglas (Computing Services)
 G. Ellison
 W.J. Harris
 F.V. Hermiston

W.S. Huggett - i/c Current Surveys
 *K.S. Lee (Computing Services)
 A.C. Ma
 A.J. Smedley
 F.E. Stephenson - i/c Tidal Survey
 M.J. Woodward
 A.L. Woollard (Computing Services)

*Joined during 1979

1979 was an extremely busy year for this section. In January W.S. Huggett and W.R. Crawford were assigned to be part of the FGGE project on the equator, and both men spent six weeks aboard CSS *Parizeau* obtaining current and current shear measurements across the equatorial undercurrent to define its limits. Six transects of the equator were made between 2°N and 2°S. A free-fall microstructure instrument was also deployed 45 times to measure microstructure shears and temperature gradients.

In May, Current Surveys combined with Offshore Oceanography in a study of the waters on and adjacent to the continental shelf on the west coast of Vancouver Island, part of the Coastal Ocean Dynamics Experiment (CODE). Thirty-five current meters were deployed along two lines running out from Estevan Point and Brooks Peninsula. All moorings were successfully retrieved and re-deployed in September, and work is underway on the analysis of the first set of data. Instruments will remain in place until September 1980.

Field work for the survey of the Gulf Island passes and Quatsino Narrows was completed, all tide gauges were recovered, and analysis of the data is underway, which will give better current predictions for inclusion in the Tide Tables.

Hydraulic Research continued its measurements of salinity and currents in the Fraser River in order to determine the behaviour of the salt wedge and to support a study of the migration pattern of salmon, requested by Department of Public Works for its Fraser River Shipping Improvement project.

Production runs of the existing mathematical model of the Fraser River were made at the request of various government and private agencies.

A field program of current, salinity and temperature measurements was carried out in the mouth of the Skeena River. Oil spill simulation models were developed to provide information for various oil port enquiries. Surface drift measurements were carried out in the western part of Juan de Fuca Strait, in cooperation with the Pacific Marine Environmental Laboratory

in Seattle. These measurements were made to test and improve a model predicting the course of potential oil spills in that area.

Tidal Survey carried out two surveys in the Arctic. One, in conjunction with the tidal group in Atlantic Region, where the records are being analysed, was the installation of three tide gauges in Peel and Franklin Straits and Prince Rupert Inlet. These gauges were recovered in June after two months' deployment. In mid-August eight pressure gauges were installed in Coronation Gulf, Queen Maud Gulf, St. Roch Basin and the connecting waterways. Three pressure gauges were deployed as barometers, and all instruments will be recovered next year.

The data from the twenty-three permanent and four temporary tide gauges are processed and analysed on a routine basis, and processing is now much more efficient with the introduction this year of a disc-oriented data processing system. Four TATS (Tidal Acquisition and Telemetry System) units were installed this year at Vancouver, Point Atkinson, Victoria and Bamfield.



COASTAL OCEAN DYNAMICS EXPERIMENT (CODE). ● Current meter mooring positions. ◆ Shore tide gauge positions. EP line positions 1, 2, 3a & 5 have offshore tide gauges.

Tidal Research completed a study of the combined effects of weather and tides upon sea levels at periods longer than two days at four British Columbia ports, and this will be published as an Institute report in 1980. The study showed large oceanic responses to air pressure and wind changes west of Vancouver Island.

As part of the Coastal Ocean Dynamics Experiment six pressure gauges were deployed in near-shore waters along the west coast of Vancouver Island and four pressure gauges were moored in waters up to 2500 m depth. The study will examine tidal and wind-driven currents and their relation to sea levels along the shore and in deeper waters. The results will improve current predictions for offshore waters and thus aid navigation, fishing and oil spill management.

DIVING UNIT

Regional Diving Officer - F.E. Stephenson

Field Hydrography:	K. Czotter	Tides & Currents:	F. Stephenson
	R. May		M. Woodward
	M. Preece		
	E. Sargent	Coastal Zone:	L. Spearing
	D. Wood		
	J. Vosburgh	Ocean Chemistry:	D. Paton
			F. Whitney
Engineering Services:	J. Galloway		
	B. Hinds	Ship Division:	G. Price

Diving Unit

This is the first year that a summary of the Institute's diving activities has been included in the Annual Report. The diving unit is a very important but nebulous group which at present consists of fourteen qualified divers - ten of whom work in the Hydrographic Division, one in Ship Division, and three in the Oceanographic Divisions. All divers perform other full time functions and their services are utilized by various sections within the Institute on a "fair exchange" basis. The task of trying to achieve this "fair exchange" is handled by the Regional Diving Officer in consultation with the divers' supervisors. The Regional Diving Officer is also responsible for diver health, training and safety, and for the purchase and maintenance of equipment used by the divers. Almost all funding is provided by the Field Hydrography and the Tidal & Current Survey sections.

NUMBER OF DIVES* PERFORMED: 1974-1979

	1979	1978	1977	1976	1975	1974
Ship Division	0	2	4	2	7	9
Field Hydrography (& Engineering Services)	3	15	2	7	2	16
Tidal & Current Survey (& Offshore Oceanography)	81	122	25	11	27	15
Coastal Zone	44	63	16	-	-	-
Ocean Chemistry & Ocean Ecology	4	12	10	-	-	-
Training & Recreation	9	17	10	4	14	17
Miscellaneous	0	1	2	3	9	0
Total	141	232	69	27	59	57

*Definition of "dive" as used in this report:

1. each diver in the water constitutes a dive, i.e. three divers in the water - three dives;
2. if a diver is out of the water more than two hours and then dives again it is a new dive;
3. if a diver dives at several locations then each location counts as a dive (regardless of the surface interval times).

Between 1974 and 1977 the number of dives* performed by the diving unit averaged 46 a year. In 1978 the number of dives increased dramatically to 232 and in 1979 there were 141 dives.

The increased diving activity these past two years was mainly due to the large number of bottom mounted pressure gauges being installed, positioned and serviced using divers. The Tidal & Current Section, Coastal Zone Oceanography and Offshore Oceanography have all benefitted tremendously from these services. Some projects currently underway would not be possible without divers and others, while possible, would yield a lower quality of data.

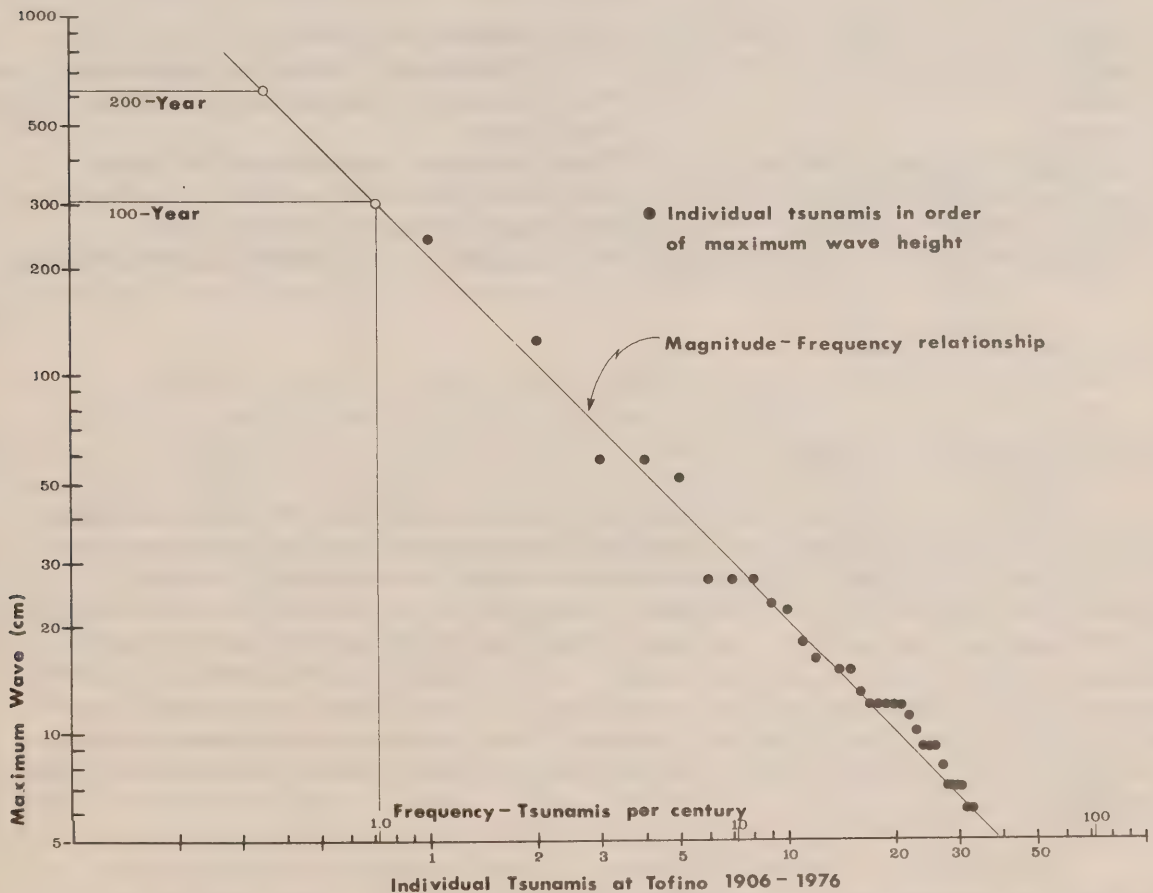
In 1979 divers also conducted important shoal examinations, observed the field tests of new equipment, installed or repaired fluorometer intakes, thermistors, tide staffs and conducted searches for lost equipment.

The diving statistics are heavily biased by the pressure gauge activity, but most dives were to a depth of approximately 15 metres for a duration of 30 minutes or less. Divers spent a total of 55 hours and 17 minutes in the water during 1979. It is anticipated that diving activity will remain fairly constant over the next few years and that the diving unit, as presently structured, will continue to meet the demands of it.

TSUNAMI ADVISER

S.O. Wigen

Investigations have continued to determine the frequency and magnitude of tsunamis to be expected on the Canadian west coast. At Tofino thirty-three had been recorded on tide records in the 71-year period 1906-1976. The largest of these was the Alaskan tsunami of 1964, with a maximum wave height of 240 cm, followed by the 1960 Chilean 126 cm tsunami. Although it is not possible to predict when the 1964 disaster will be equalled or exceeded, a logarithmic plot of the events, as shown on the accompanying diagram, is valuable in estimating the size of a typical once-in-a-century tsunami. Such an estimate is necessary for coastal zone management and for the development of land use policies in areas where tsunamis pose a potential threat.



Efforts to stimulate public awareness of tsunamis have achieved some success. An increasing number of engineering firms are consulting the Institute regarding tsunami hazard during their planning of new industrial and port facilities for low-lying coastal areas.

Resources have been developed at the Institute during 1979 to support tsunami investigation, and a tsunami library of more than 1000 papers has been catalogued and made available for researchers.

Internationally, the Institute took the lead in developing a joint Canada/U.S. report on the use of satellites in the tsunami warning system. The tsunami adviser has participated in tsunami workshops in California and Hawaii, and in tsunami symposia at the Pacific Science Congress, Khabarovsk, USSR and the International Union of Geodesy and Geophysics, Canberra, Australia. Liaison visits have been made to tsunami warning centers at Ewa Beach, Hawaii; Palmer, Alaska; and Tokyo and Osaka, Japan to encourage international co-operation and improved technology for more effective warnings to all Pacific rim countries.

COMPUTING SERVICES SECTION

K. Teng - Head

R.E. Johns	A.H. Wharton - FSRG
D.B. Smith	A.L. Woollard - Tides & Currents
S.R. Oraas	*K. Holtham - Numerical Modelling
J.W. Butcher	*B. Clark
A.N. Douglas - Tides & Currents	**R.G. Hlady - Management Services
M.G. Foreman - Numerical Modelling	P. Lacroix
J.S. Page - Ocean Chemistry	*K. Lee - Tides & Currents
P.J. Richards - Numerical Modelling	*J. Linguanti - Offshore Oceanography

*Joined in 1979

**Left in 1979

Univac 1106 Computer System

The Univac system continued to evolve in 1979 with some hardware changes and software upgrades. A second Fastrand controller was purchased and installed in February; this provides a second access path to the Fastrand drums (used for on-line mass storage). The result has been improved batch through-put and demand response times via reduced I/O contention and consequent access queuing to the drums. To provide the required I/O channel, an on-site 1004 reader/printer was replaced by the former Vancouver remote batch terminal (now operating as a remote 1004, through the communications controller). At the same time, the seldom-used card punch was removed from the system.

In October, a second Uniservo 16 dual density tape drive was installed, replacing one of the older 800-bpi drives. This enables more extensive use of magnetic tapes recorded at 1600-bpi. Also, two more medium-speed (1200 bps) communications ports were added, bringing the total to six at 300, six at 1200, and two at 1800 for asynchronous terminals. The proliferation of computer terminals continued, including an HP 2635A printing terminal with upper and lower-case capability.

A new drum plotter (Houston Instruments DP8S3, with 3 pens) was finally delivered in November. This will replace an old off-line Calcomp 563, and will be driven from the Univac through an on-line controller; software development to support the new plotter has been started.

Software developments included the following:

- The batch scheduling algorithm was revised to give a higher priority and hence a shorter turn-around time for jobs requiring relatively smaller amounts of computer time;
- New versions of ASCII Fortran, COBOL, PL/I, APL, Sort/Merge, Plot queuing, Plot previewing, Tape translation, and the IMSL Mathematical and Statistical library were implemented;
- The LINPACK subroutine library for solving systems of linear algebraic equations was installed;
- An asynchronous communications handler to enable transmission of data from/to foreign devices (such as programmable calculators) was developed;
- The computerized Library Book Catalogue project was resurrected; the database was redesigned, and the data entry program was re-written to be much smaller and faster.

An "Introductory Guide to the Univac 1106 Computer System" was printed in March, and a "Univac 1106 Users' Manual" is now available in machine-printable form. Information relating to recent or upcoming changes to system software, operations policy, or scheduled system down-time was publicized via the "Systems and Operations Notices" series of system news files.

Computing Services staff performed an informal Bench-mark Study in the spring, to determine that the workload statistics (\$-value) and rate structure are realistic, when compared to an external service bureau. In the fall, the staff participated in formal bench-mark studies, as part of an evaluation of the Univac 1106, conducted by the Evaluation and Audit Branch of departmental headquarters. A major objective of this study was to determine whether it is cost-effective to continue the operation of the Univac 1106; the final results are expected early in 1980, but preliminary data indicate the system is cost-effective.

Minor adjustments were made in the accounting structure. In August, the overnight rate factor (60%) was extended to cover the entire weekend. In October, a charge was instituted for catalogued mass storage files that are rolled out to tape; this charge is 1/3 of that for on-line files. System utilization levelled off in 1979, as indicated in the following:

Average monthly usage (\$)		
	1978	1979
OAS users	32,439	31,832
Other users	<u>5,706</u>	<u>9,391</u>
Total	38,145	41,223

Automated Cartography

In 1979 the digitizing system became operational. The digitizing program DIGNTX was received from CHS headquarters in Ottawa. It requires extensive modifications to run under RSX-11M on our PDP-11 minicomputer and to accept our different hardware configuration. A combined beeper and talk box was designed and built by Institute Electronics for connection to the digitizing system. A scribing cursor was designed and built by an outside company. Also, modifications were made to the micro-processor controlled interface for the digitizing table to control the talk box and to give the table the functions required by DIGNTX. The system was used successfully by the Victoria Capital Regional District to digitize property boundaries from a series of map sheets. However, the table was found to have errors which were too large for Chart Production, and was therefore sent back to the factory for repairs.

Cartographers from the Chart Production section have been trained in the operation of the automated cartography equipment and can now produce their own borders and lattices on it. This involves encoding specifications onto punched cards, running them through the Univac 1106, and then making any necessary modifications using GOMADS and other interactive programs on the PDP-11. To assist in the production of compartment charts and borders with insets, a program was written to allow the user to interactively shift and rotate various elements within a graphics file. An additional program was written to assist in the production of wind velocity charts, and these are now being drawn on the Kongsberg photoplotter.

Mini/Micro Computing

Activity in the area of minicomputers and microcomputers in 1979 reflects the trend in computer technology toward distributed intelligence.

The Tides and Currents group moved to a greater use of the multi-user operating system on their Hewlett-Packard 2100 system. Coastal Zone Oceanography acquired a disk drive for their HP2112 system, greatly enhancing the program development capability of that system. The Ocean Mixing Section added a programmer for Programmable Read-Only Memories (PROMS) to their system, which together with an enhanced Cross-Assembler for INTEL 8080/8085 microprograms, provides the Hewlett-Packard users with a very powerful facility for program development for microprocessor-based equipment.

Microcomputing projects this year included enhancements to the SCRIBE high speed data acquisition system and Remote Sensing Section's SPECTRE spectrometer data system as well as the development of the Acoustic Doppler Current Meter (ADCM) jointly by Institute Electronics Engineering Group and Coastal Oceanography Section with Computing Services doing the microprogramming.

ENGINEERING SERVICES

J.V. Watt - Head

Institute Electronics

*** T.A. Curran - Project Engineer	B.A. Johnson
L.W. Dorosh	R. Loschiavo
J.L. Galloway - Project Engineer	R.A. Muse
*** D.G. Gregson	M. Osborne
E.W. Hinds	*M. Stone
C. Hollinger	W.R. Taylor - Head, Technical Support

* Joined in 1979

*** Proceeded on educational leave during 1979

Institute Electronics provides electronics engineering and technical support for survey, research and ship operations in the Pacific Region. The demands made upon the electronics section remained at a high level during 1979 and resulted in the involvement of the staff of engineers and technologists in numerous interesting activities. The capability of the section to undertake engineering projects was significantly reduced this year by the temporary loss of two of the staff who have returned to university to seek advanced degrees.

Electronics Engineering Group

Services to the Institute during the past year involved the usual variety of consultation activities and minor modifications but only a very limited number of major activities. In a departure from the role undertaken in the past, one of the two Project Engineers, Mr. Curran carried his current shear probe beyond the development and test phase into the field to collect data during the 1979 FGGE tropical experiment. In the aftermath of this two month cruise he has spent considerable effort examining the data collected and as of September has undertaken course work at U.B.C. which will lead to a M.Sc. in Oceanography.

A major engineering effort has been applied to the development of a gated-doppler current profiler system during 1979. Initial field tests have identified a number of design improvements which should be completed early in 1980. Other projects undertaken during the past year include modifications to the fluormetry data acquisition system, modifications to the PHAS (Hydrographic data acquisition system) system, and the building of a microprocessor development system and PROM programmer based on an HP 2645 terminal linked to the UNIVAC 1106. A further major effort has gone into the contracting and management of studies to examine methods of detecting pingo-like-features in the Beaufort Sea. These studies which are being financed by HARP (High Arctic Research Program) funds are being conducted in close cooperation with Field Hydrography.

Technical Support Group

During 1979 the Technical Support Group provided equipment maintenance, preparations, installations and field support to the West Coast Survey (*Parizeau*), Mackenzie River Survey (*Radium Express*), a number of smaller coastal surveys (*Richardson*) and shore parties at Vancouver, Pitt Lake and Harrison Lake. The commissioning of the barge *Pender* necessitated the installation of an SSB and VHF radio station.

New field equipment acquired in 1979 and injected into the maintenance program included two Ross portable survey depth sounders, one Simrad depth sounder, one MRS III positioning system, one communications and paging system, four portable radio transceivers, and a shipboard Communal Aerial System to supply AM, FM and TV reception throughout a ship.

The group was involved in various equipment trials which evaluated a number of launch echo sounders, a shipboard correlation echo sounder processor (CESP III) and a new model of a large, shipboard echo sounder recorder. Other projects undertaken this past year included working with field hydrography to overcome aeration and propeller noise interference problems with echo sounder installations in high speed launches and on the modification of two HF radio transceivers to enable the units to drive and control a single linear amplifier. Considerable effort in assisting the navigation group of field hydrography saw the eventual successful integration of the rho-rho Loran-C system with the dual-channel, transit satellite navigation system in the BIONAV configuration.

MECHANICAL ENGINEERING

G.R. Smith - Project Engineer

A.E. Moody

J. Steeples - Head, Mechanical Support

Along with his Industrial Liaison and contract supervision activities Mr. Smith has continued to provide general supervision of the Mechanical shops and Mechanical Engineering services. With the assistance of Mr. D. Redman, an engineering technician/draftsman whose time is shared with Ship Division, the group has effectively handled the routine design work associated with numerous minor projects.

The Mechanical Support Group which provides shops facilities and assistance to users in addition to meeting requests for shops services, had a very active 1979. All sections of IOS were making use of the machining and fabricating facilities and accordingly a high level of direct support and provision of advice and assistance was required. Many projects, which varied from repairs and modifications to the design and construction of prototype devices, were undertaken.

Projects were at times completed with the able participation of Ship Division's Depot Shops and with the utilization of a contractor who provided on-the-premises machining services to accommodate overload situations. Both the above techniques have proven highly successful in achieving good quality workmanship and in ensuring that all deadlines were met.

As an indication of the type of work undertaken during 1979 the following is a sampling of the variety of projects completed: pressure cases for equipment (Ocean Mixing, Coastal Zone Oceanography), salinity syphoning device (Frozen Sea Research), protective cage for a transducer (Coastal Zone Oceanography), Geiger counter sense head (Ocean Chemistry), XCTD modification to permit water tunnel tests (Offshore Oceanography), hydraulic housing for *Pisces IV* (Ship Division), milling of print bars (Computing Services) and the usual array of special purpose brackets, panels, plates and such items for all sections of IOS.

INDUSTRIAL LIAISON AND CONTRACTING

G.R. Smith

The Make-or-Buy policy and the DSS Unsolicited Proposal scheme have been positive steps towards promoting a research and development capability in the Canadian private sector. In spite of these policies, the overall level of Research and Development in Canada has not changed significantly. In addition, the effects of continued financial restraint are beginning to show. There has been a reduction in the level of contracting by departments, and the competition for unsolicited proposal funding has increased considerably. Although the level of funding for unsolicited proposals has increased steadily, so has the number of proposals received. At present, requests for funding are more than double available funds. Even though the overall picture does not look encouraging, those companies who have taken the initiative in preparing proposals that ultimately result in marketable products and services have done well.

At the Institute of Ocean Sciences, an active contract program is still in effect, but the large increases seen in previous years did not take place in 1979/80. It is unreasonable to expect these increases to continue unless major new programs are funded. However it is anticipated that the present levels of contracting will be maintained in 1980/81 if Institute funds are not further reduced.

For companies involved in marine sciences, 1979/80 has been a year of continued expansion in both personnel and markets. Most companies have reduced their dependence on government contracting and several are now involved in international markets. This rapid expansion now makes the need for a Marine Technology Centre adjacent to the Institute more obvious. This centre is expected to provide a focal point for marine sciences on the west coast and attract an increased volume of business. The concept of a Marine Technology Centre is not new, but in 1979/80, the Provincial Government gave its support to the development. As a result, the British Columbia Development Corporation was invited to undertake the project and a lease agreement for the property was finalized. The first phase of construction will be completed in 1980 and is expected to be fully occupied shortly after completion. Construction of further phases will be governed by the demand for space.

OCEANOGRAPHIC DIVISIONS

OCEAN PHYSICS DIVISION

*P.W. Nasmyth - Chief of Division

*Retired during 1979

The programs of the Ocean Physics Division are mostly directed towards three main objectives: improving the knowledge and understanding of the oceanography of the waters near the B.C. Coast, improving the knowledge and understanding of oceanographic processes important in the Canadian Arctic, and contributing to the understanding of the ways in which the oceans interact with the atmosphere on the scales relevant to climate. Using the expertise gained from their work in these areas, scientists from the Division are frequently called upon to advise local, national and international bodies on matters of direct practical concern, such as the environmental risk associated with an Arctic tanker port or the possible fate of waste material dumped at a particular location. This year major efforts were made in the First GARP Global Experiment (designed to obtain the first complete description of the behaviour of the world's atmosphere over the annual cycle), and in the Coastal Ocean Dynamics Experiment intended to improve understanding of water movements on the continental shelf west of Vancouver Island. However much other work was also accomplished as may be seen from the following pages.

FROZEN SEA RESEARCH GROUP

E.L. Lewis - Head

R.A. Cooke
 *P. Johnston
 A.W. Koppel
 R.A. Lake
 J.M. McNeill
 *H. Melling
 R.G. Perkin

D.L. Richards
 *B. Smiley
 R.B. Sudar
 D.R. Topham
 A. Wharton - Computing
 Services

*Joined in 1979

During 1979 the Frozen Sea Research Group (FSRG) made field trips

concerned with the oceanography of Bridport Inlet on the southern shore of Melville Island; tested measurement techniques used to determine the heat flow from polynyas (areas of open water within growing sea ice); joined with other agencies in acquiring field data aimed at the development of a computer model for sea ice motion in the Beaufort Sea near shore and acquired data from the sill of a polluted Greenland fjord from instruments deployed in 1978. Work was also carried out on the physics of underwater oil well blowouts; on instrument development, in particular a "salinity sucker" a device for looking for ice crystals in water; and on the new "Practical Salinity Scale 1978".

A study of physical oceanography in Bridport Inlet (Melville Island), initiated in 1978, continued through 1979. Bridport Inlet is the proposed northern terminal for the Arctic Pilot Project whereby liquid natural gas would be transported from the gas fields of the Sverdrup Basin to southern markets year round. In early March the tracked vehicles and sleds forming the logistic base for winter operations were moved from Resolute Bay to Rae Point by C-130 transport aircraft and then were driven for four days along the shoreline of Melville Island to Bridport Inlet. During the remainder of March, 61 CTD casts were taken, six Aanderaa recording current meters were deployed to await summer recovery, one tide gauge deployed in August 1979 was recovered and two more gauges were deployed. In addition an ultrasonic current meter was used in conjunction with a prototype conductivity-temperature (CT) chain to investigate internal waves within the inlet. Operations were made difficult by high winds (40-50 knots) coupled with low temperatures (-30°C to -45°C). Water structure showed a marked difference between water inside and outside the inlet. The recording current meters which provided a record of 100-125 days' duration showed complex currents at the inlet entrance. Within the inlet significant currents were sustained only during runoff in late July. Internal waves were evident on CTD profiles and well-defined internal wave packets were recorded by the ultrasonic current meter and CT chain. Work was initiated with the modelling group at the Institute to model residual flow within Bridport Inlet. Further field work is planned.

The second stage of the Polynya Project, intended to test measurement techniques, was enacted. A combined team comprising members of FSRG, AES and BIO established camps on Dundas Island, N.W.T., to make preliminary measurements of heat flux from an area of open water under conditions of extreme temperature difference. Unfortunately conditions were far from ideal, the only open water consisting of two adjacent patches approximately 200 metres across, bordered by a large rubble field. These open areas were short lived, freezing over before the measurements could be completed.

FSRG completed operational flight trials of the radio controlled model aircraft and gathered temperature data over both solid ice and open water. In general the aircraft and its data telemetry system performed satisfactorily under arctic conditions, but development has continued during the summer with the addition of on-board positioning equipment accurate to ± 2 metres based on the Decca Mini-fix system, and an improved control system.

Mean air temperature profiles were obtained from a 4 metre mast which suggest that, over fetches of up to 60 metres, the major temperature drop takes place within a distance less than one metre from the water surface. Moored current meters in the vicinity of the polynya indicated that over a 10-day period, the tidal flows from the north, that is from areas of thin or

broken ice, were consistently cooler than flows from the south, the direction of unbroken ice cover.

Unfortunately neither the AES nor BIO parties were able to obtain data over open water since the open areas closed early in the trip, but both achieved full tests of their equipment under operational conditions and on the over-ice atmospheric boundary layer.

In the second half of 1979, we became involved in the Beaufort Sea Winter Ice Experiment, a joint government/industry study aimed at the development of a computer model to predict the motion of sea ice. Such prediction requires an understanding of the combined effects of winds, ocean currents, the rotation of the earth and the strength of ice on the ultimate speed and direction of ice drift. To provide data to test the models being developed, a co-ordinated observation program of the ice, ocean and atmosphere over an area of 100,000 square kilometres in the southeastern Beaufort Sea was conducted in November and December 1979. We carried out a survey of ocean temperature and salinity over the area to a depth of 400 metres. These measurements will be used to calculate the steady current at the surface of the ocean and its effect on ice movement. Due to unusually mild weather, which resulted in relatively thin ice for the season, and to the limited amount of daylight with encroaching polar winter, most of the measurement sites were visited using a helicopter equipped for instrument flying and capable of keeping its full weight off the ice while stationary. Several more distant sites (up to 400 km offshore) were visited using a ski-equipped aircraft. The survey was successfully completed in six days. Analysis of the data acquired, and FSRG participation in computer development, will continue into 1980.



Acquisition of oceanographic data through the sea ice in late November 1979 about 300 km north of the Beaufort Sea coast. Special care had to be taken to put this Twin Otter aircraft down on the thin ice existing at that time of year and it was preceded by a Cessna 185 that could safely land on much thinner ice and radio back the measured thickness to the Otter pilot. The observers are recovering the conductivity-temperature depth probe after it had been lowered using the small portable winch shown.

Mine tailings were being dumped into Agfaidikavsa Fjord in Greenland with the expectation that the sill at the head of this small fjord would retain the sediments. However, the pollutants were escaping and a current meter installed on the sill to monitor conditions showed that relatively high currents could occur during "events" resulting from denser water spilling over the sill. This displaces the polluted water in the small fjord raising it over the level of the sill so that it can pass in Quamarajuk Fjord. Analysis of this data is continuing. The mine has recently improved its process to remove most of the dangerous metals from the effluent.

The laboratory studies of gas hydrate formation and out-gassing of oil drops were completed under a contract let to the University of Calgary. The vertical flow, high pressure water tunnel designed and built in 1978 was successfully operated at pressures up to 1300 psi and the behaviour of hydrocarbon gas bubbles were studied under conditions of both constant pressure and simulated rise (decreasing pressure) over a range 1300 psi. The formation of gas hydrates was demonstrated under a variety of conditions which suggests that, in a blowout occurring at depths greater than 500 metres, all the gas would be converted to solid hydrate. Experiments on the decompression of gas saturated oil drops showed that in the absence of hydrate particles the dissolved gas diffused directly into the water column. With hydrate particles present in the water column, the oil drops became coated with hydrate which decomposed under simulated rise conditions. At no time did out-gassing result in fragmentation of the oil drops.

A further contract has been let to elucidate some features of the present results, in particular, the role played by background dissolved gas in controlling the induction time of the formation process.

An issue of interest to arctic oceanographers for many years is the apparent super-cooling of waters beneath growing sea ice. A "salinity sucker" has been constructed which is capable of measuring the conductivity and temperature of the water pumped past these sensors while collecting entrained ice crystals on a filter. Super-cooling is relieved by the passage of the water through the filter and the amount of ice can be measured *in situ* by melting the ice in a closed chamber and measuring the resulting change in salinity. This information will further the understanding of ice formation and growth as it occurs in nature, and will also provide a means of ascertaining the heat balance in the water of polynya and thereby supplement the atmospheric measurements.

Salinity, or the fraction by weight of salt dissolved in seawater, is a quantity in everyday use by oceanographers. However there are serious problems in present definitions making the uncertainty in inter-institutional comparisons considerably greater than the precision of the measurement. In response to the need for a universally accepted method of calculating salinity, the Joint Panel on Oceanographic Tables and Standards generated a new and more accurate data set based on our recommendation for the "Practical Salinity Scale 1978". We had the task of providing the definition and fitting these data to a set of empirical equations valid over the entire oceanographic range of variables. This was done and the equations and the definition of salinity were accepted by the IAPSO at the IUGG meeting in Canberra in December 1979.

Giving environmental advice to committees concerned with arctic industrial development has now become a major task which requires about two person-years annually. The Arctic Water Advisory Committee probably gives the most work of the eight in which we presently participate.

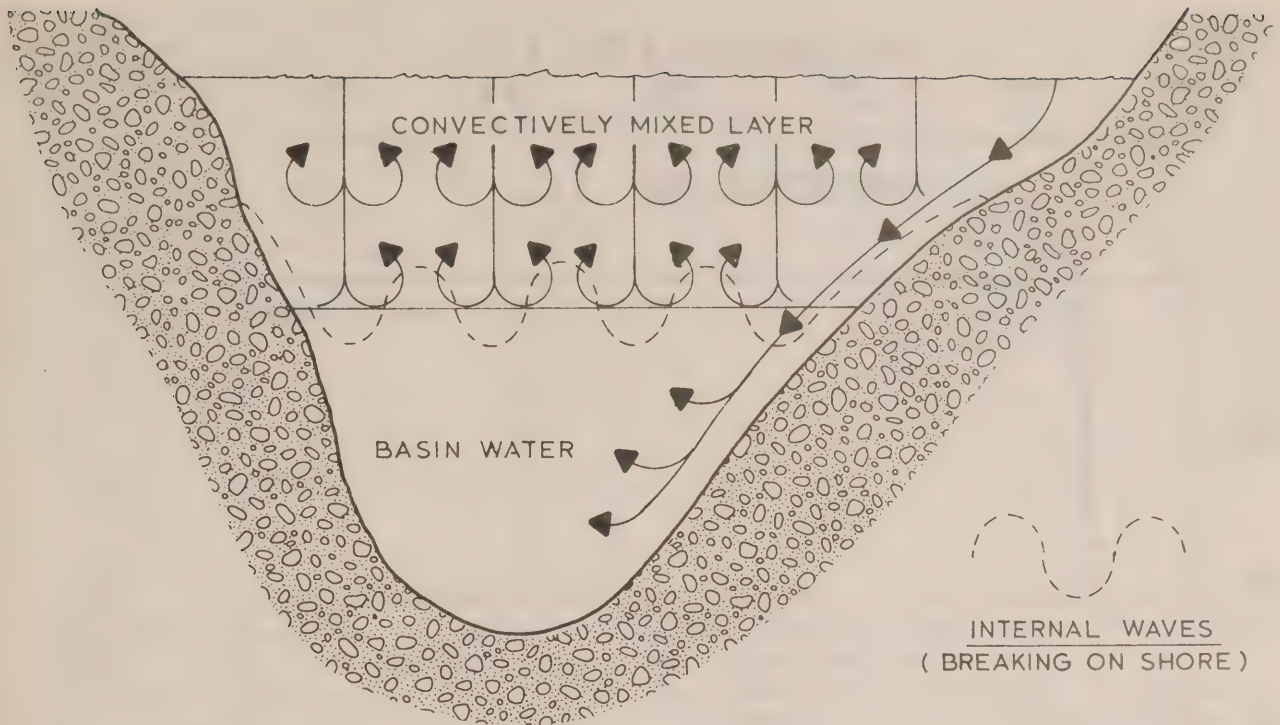


Figure 1. Sea ice is far less salty than the water from which it grows and the remaining salt is rejected at the freezing interface. This produces a vertical convective circulation which penetrates downwards to a depth depending on the water density structure to produce a two-layer system, as shown in this schematic. A typical depth of the convectively mixed layer might be 50 metres and, where the water is shallow, the mixing process is not complete before the cold, dense brine rejected by the ice hits bottom and flows down the slope. This process has been observed in bays, and it is very probable that it occurs on a much larger scale in the Arctic Ocean as a whole, which has shelf seas of area about twice that of the basin. It has been noted that currents of dense water along the bottom are often mixed in by breaking internal waves, a point made schematically in the figure.

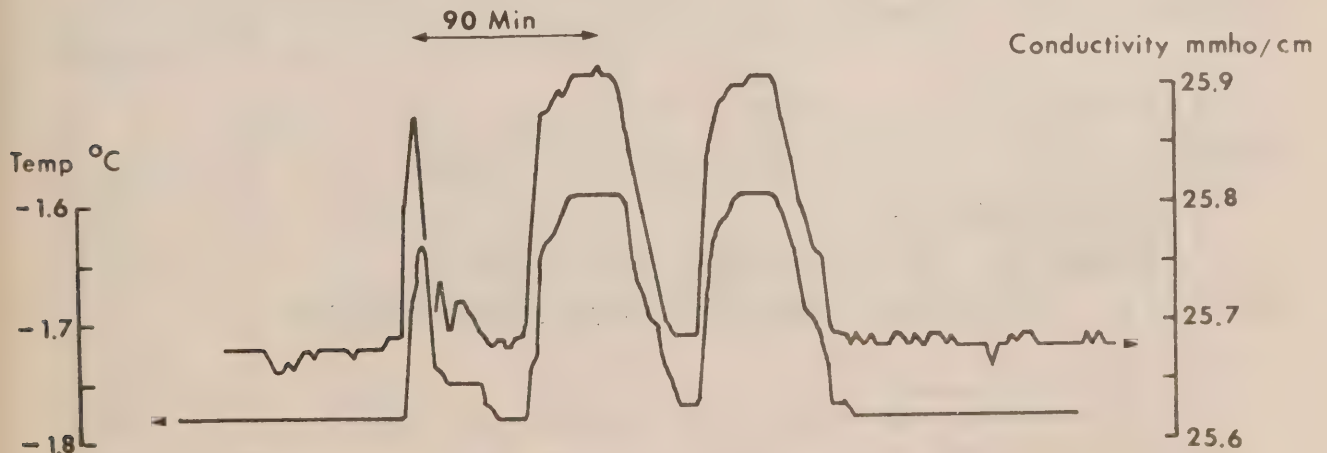


Figure 2 shows such a wave pattern, as described in figure 1, on the interface between the mixed layer and basin water at Bridport Inlet, as recorded by our "salinity chain".

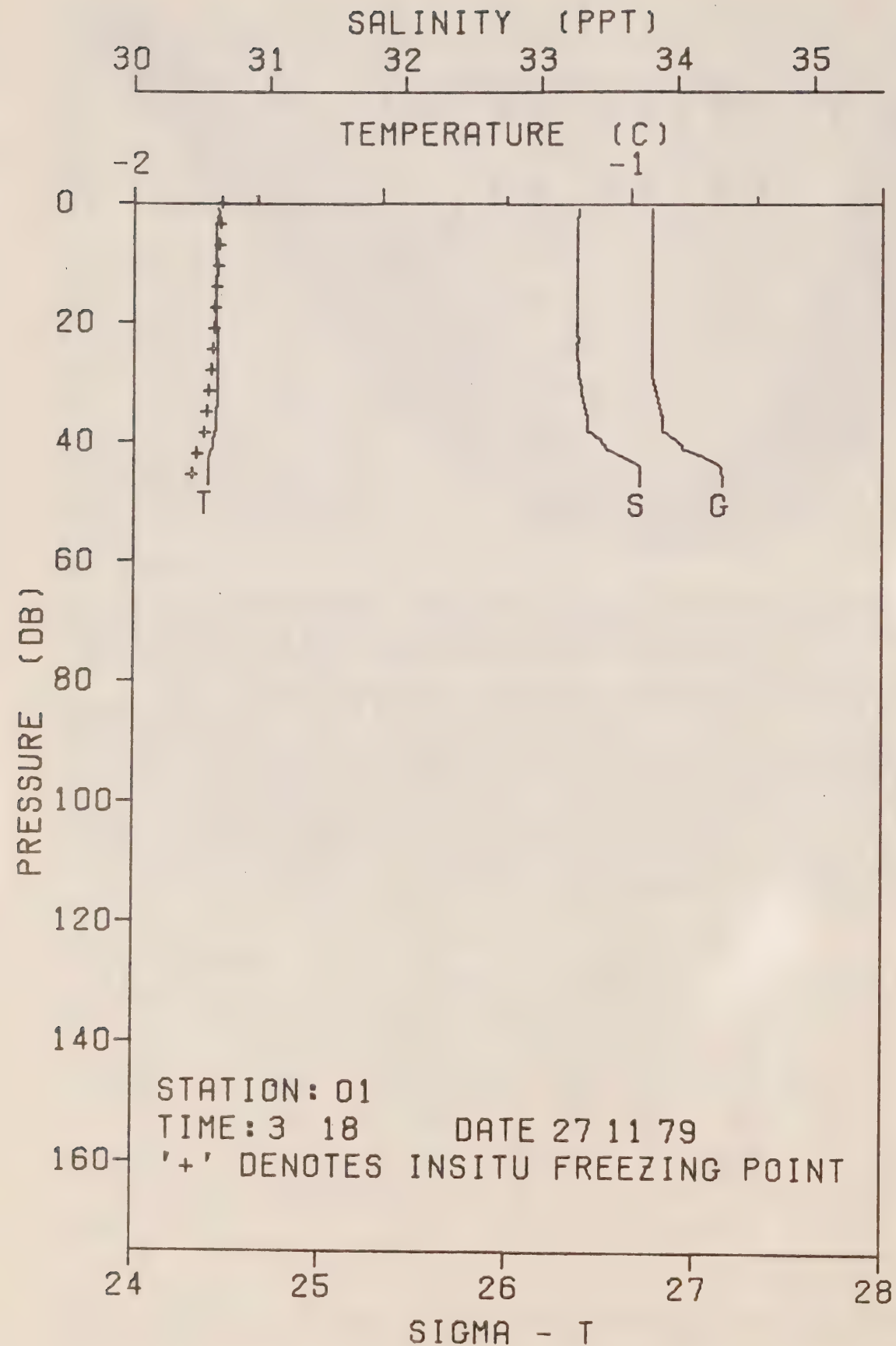


Figure 3 shows cold saline water on the bottom at a location about 100 km north of the Beaufort Sea coast at a depth of 48 m water. The sea is nearly at the freezing point (marked with crosses on the figure) from top to bottom but shows a sudden increase in salinity and, hence, in density, in the last 8 m.

COASTAL ZONE OCEANOGRAPHY

D.M. Farmer - Head

W.H. Bell
 R.H. Bigham
 H.J. Freeland
 L. Giovando
 G. Kamitakahara

A.P. Lee
 J.H. Meikle
 D.G. Sieberg
 L.A. Spearing
 J.A. Stickland
 D.J. Stucchi
 *Z.W. Xia

*Joined in 1979

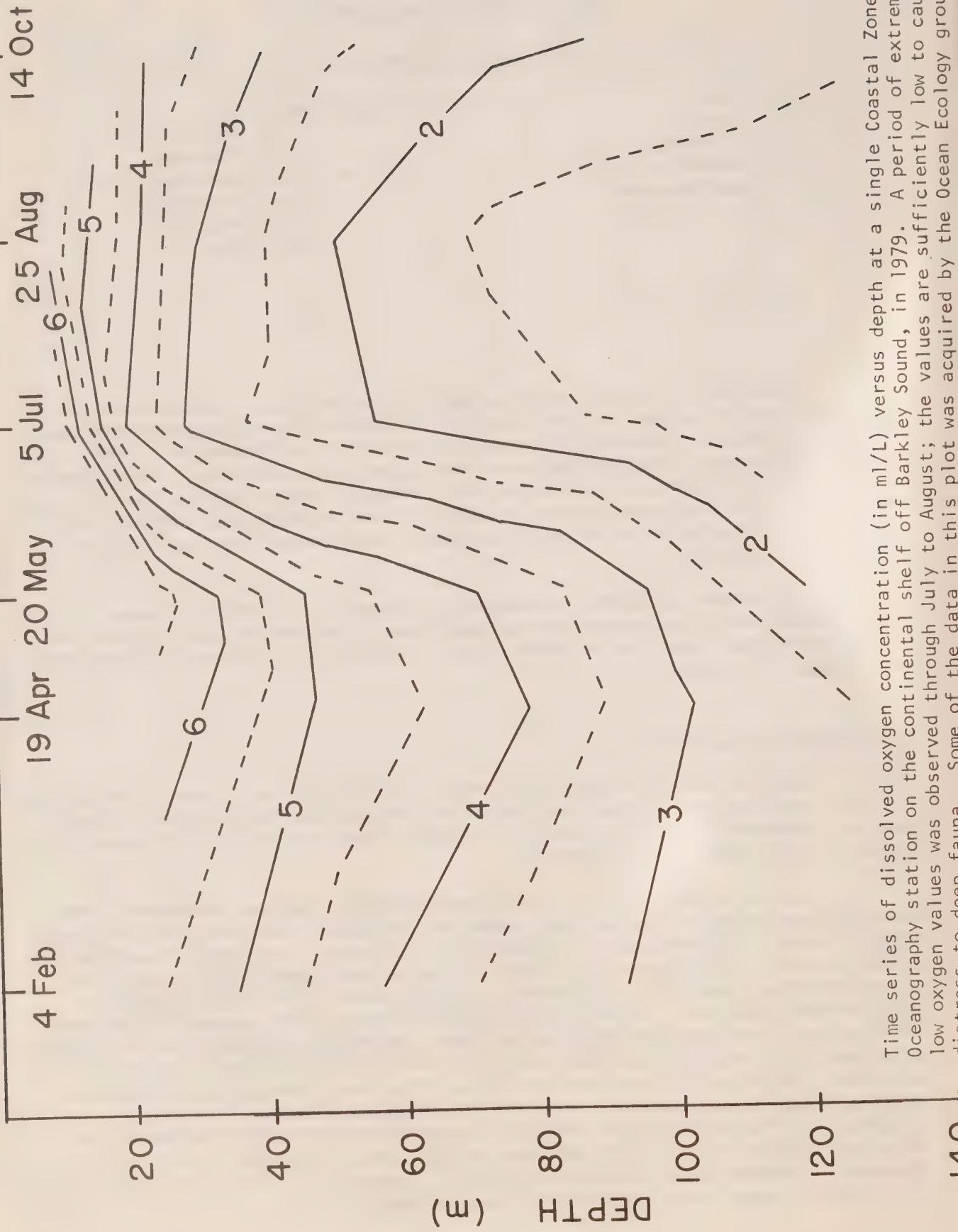
This year Coastal Zone embarked on a major field operation on the continental shelf as part of the Institute's Coastal Ocean Dynamics Experiment (CODE). A line of current meter moorings formed the southernmost of the experimental arrays, and initial data from these look promising. The dynamics of shelf waters critically influence the flushing of deep estuaries and we have taken the unique opportunity provided by the experimental work on the shelf to study exchanges with Alberni Inlet. Early data from this project also look promising.

A workshop on Fjord Oceanography, funded by the NATO Advanced Studies Institute, was hosted at the Institute. One hundred and two scientists from 10 different countries attended with interests in the physics, chemistry and biology of fjords.

Continental Shelf Project

This is the first year of a major effort by Coastal Zone Oceanography to study some aspects of the circulation on the continental shelf and slope west of Vancouver Island. During 1979 Coastal Zone sent a total of seven cruises to the shelf on this project.

In April 1979 four current meter moorings, and one anemometer buoy, were deployed along a line perpendicular to the shelf break and just south of Barkley Sound. All moorings had sub-surface buoyancy, and carried Aanderaa current meters. Unfortunately, a short time before scheduled recovery, two of our moorings were hit by mid-water trawling vessels and were dragged a considerable distance. Despite this, current meters were recovered from the affected moorings, and the data return from the entire deployment is actually quite good; 6½ complete records, out of a total of 10 deployed, have been returned. Furthermore, data are available from every mooring for almost the entire period of deployment. The mooring array was recovered in early October, and the entire array has been redeployed. We hope to maintain the array until May 1981, so that two complete seasonal cycles will have been observed. Current meter processing has just begun (as of writing) and it is too early to come to any significant conclusions.



Time series of dissolved oxygen concentration (in ml/L) versus depth at a single Coastal Zone Oceanography station on the continental shelf off Barkley Sound, in 1979. A period of extremely low oxygen values was observed through July to August; the values are sufficiently low to cause distress to deep fauna. Some of the data in this plot was acquired by the Ocean Ecology group.

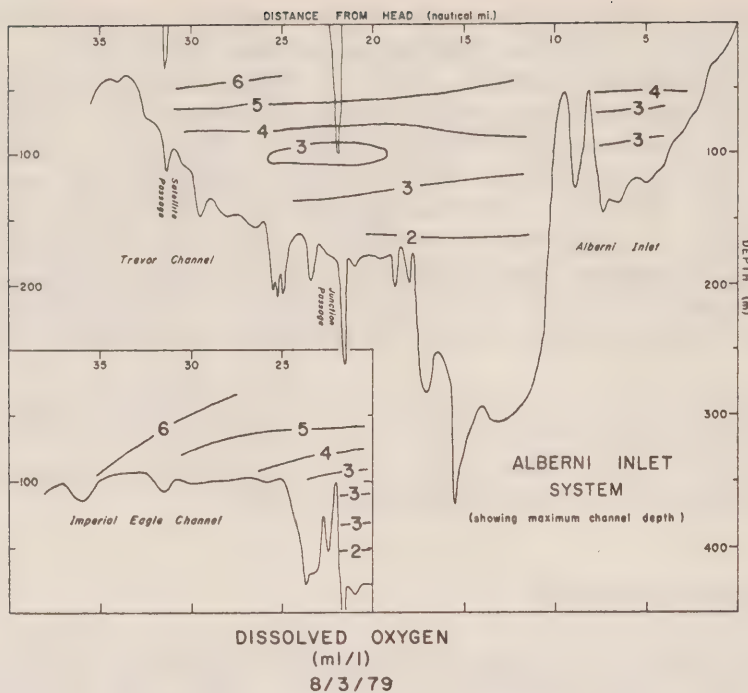
Temperature, salinity and dissolved oxygen concentrations were measured on each cruise, and the results have been surprising. During a two to three month period in mid-summer, 1979, a water mass encroached on the shelf which was distinguished by high density and very low oxygen concentration. The oxygen is low enough to cause serious distress to bottom living and deep swimming marine animals. (The oxygen concentration values were below one ml/L at the bottom.) It remains to be seen whether or not this is an annual phenomenon. A preliminary analysis suggests that this water mass could not have come directly from offshore, for several reasons, and so we conclude that alongshore drift, or advection, must be responsible. The test of that hypothesis must await detailed analysis of the current meter records.

The shelf project is being run in close collaboration with the project in Alberni Inlet described below. It is hoped that the study on the continental shelf will help identify the sources of water that are involved in the deep-water renewal events in Alberni Inlet.

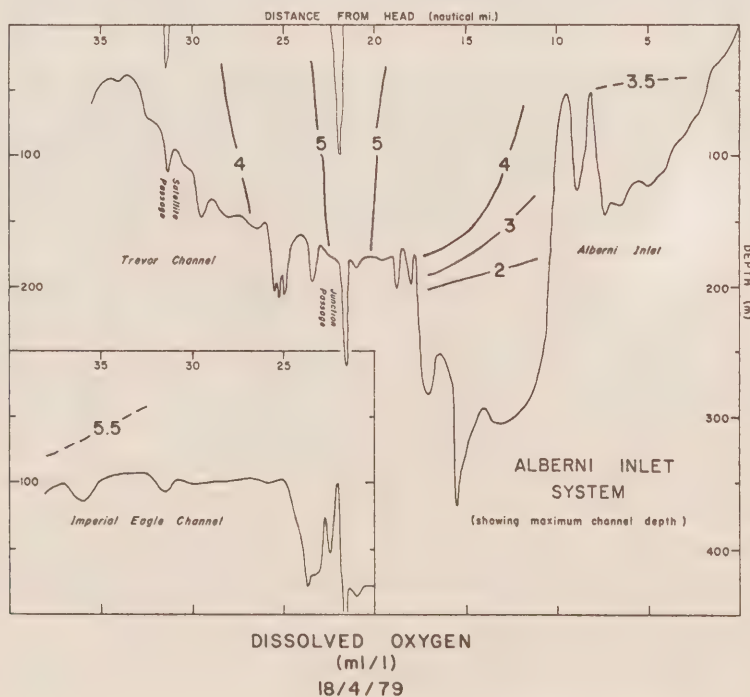
Alberni Inlet Circulation Study

An investigation of some oceanographic features of the Alberni Inlet - Barkley Sound fjord system was begun in 1979. In particular, it is intended to study the deep water circulation, including the inter-relationship with upwelling on the continental shelf. Data are being gathered with two moored instrument arrays, one in each major basin of Alberni Inlet. The instruments are recording current speed and direction, water temperature and salinity at half-hourly intervals at three depths. In addition, hydrographic cruises are being conducted, every five or six weeks, to obtain water structure profiles, including temperature, salinity and dissolved oxygen, at fifteen stations throughout the system. Similar data will be provided by the Continental Shelf Programme for the coastal waters adjacent to Barkley Sound, so that the influence of coastal phenomena on fjord circulation can be examined.

From a study of historical data for Alberni Inlet, available mainly for the inner basin, it seemed likely that shelf water played a major role in the fjord circulation, but principally during the late winter and spring months, when the deep water in the basin underwent an annual renewal. Then, it was thought, the system became relatively quiescent and diffusive processes played the dominant role in changing the deep water structure for the remainder of the year. It now appears that the quiescent period may be considerably shorter than previously suggested. The first cruise of the year, in late January, showed that some renewal of the deep basin water had already occurred, the dissolved oxygen values being much increased. As the upwelling season progressed through May and June, dense water appeared on the shelf, resulting in an additional substantial replacement of fjord water. (It remains to be shown whether the dense shelf water is the result of upwelling or advective processes.) The denser water, as it continued to flow into the fjord, decreased in oxygen content with time, so that dissolved oxygen levels in Alberni Inlet were gradually reduced by this mechanism. Subsequent cruises showed that shelf water was still exerting an influence on the whole Alberni Inlet system at least to the end of August. One result of a preliminary examination of the data has been to suggest that the system is very dynamic,



Dissolved oxygen profiles obtained by Coastal Zone Oceanography in Alberni Inlet showing a typical structure (above, March) and an atypical structure (below, April) wherein it is evident that an influx of "new" water is underway through Junction Passage, with subsequent spreading in both directions along the Inlet, as evidenced by the high oxygen values centred on Junction Passage.



with changes at the fjord mouth being advected throughout the system in no more than a few days.

To date only one set of data from the moored instruments has been processed. The period covered by these data is from April to August at Junction Passage and from May to August at Sproat Narrows. The prominent feature in these data is the well-defined dense inflow period that occurred from May 20 to July 5 at both locations.

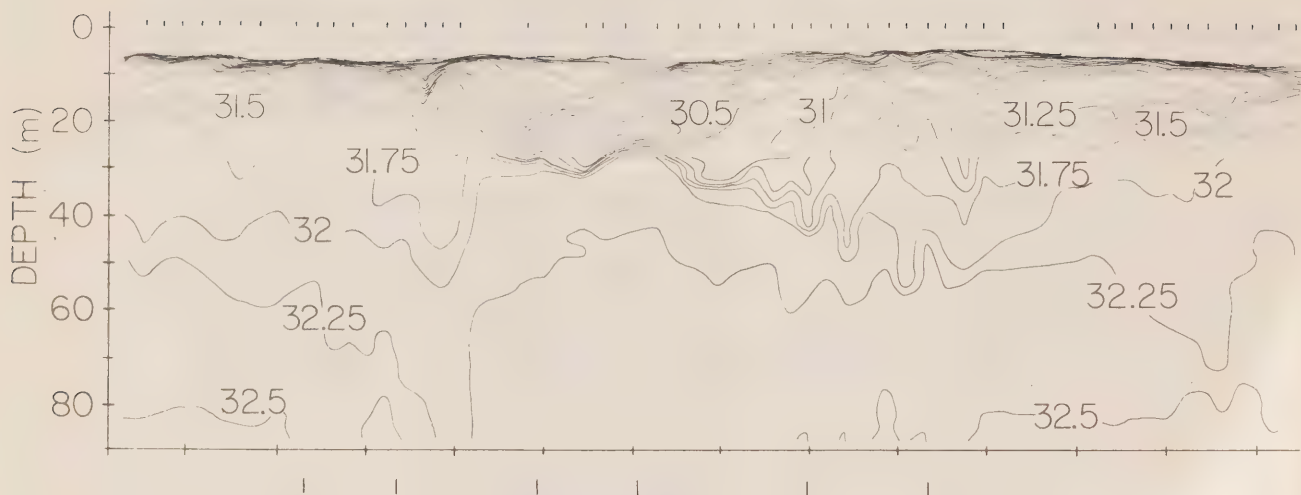
At Junction Passage the strongest inflow currents (30 cm/s) were recorded near the bottom (205 m) well below the 100 m sill level. Furthermore, the strong inflow current occurred in three bursts of four to five days duration. At mid-depth (145 m) the current speeds were lower and the burst-like character was not as well defined as that at 205 m. At both depths a tidal signal was evident but it was not of sufficient amplitude to stop the inflow. As expected, salinity (hence density) at both depths increased during this period.

At the Sproat Narrows mooring the strongest (40 cm/s) currents were recorded near the bottom and, generally, the current speeds were larger than those recorded at the Junction Passage mooring. Unlike the Junction Passage data, the inflow currents here are half-wave rectified; strong inflow current during the flood tide, and negligible currents during the ebb tide. The salinity data does not consistently increase during this period - this could be due to drift problems with a conductivity sensor. However, there is a clear tidal signal in the salinity data with high salinities coincident with strong flood current indicative of a density current similar to that seen in Rupert-Holbert Inlet.

The Dynamics of Flow over Sills

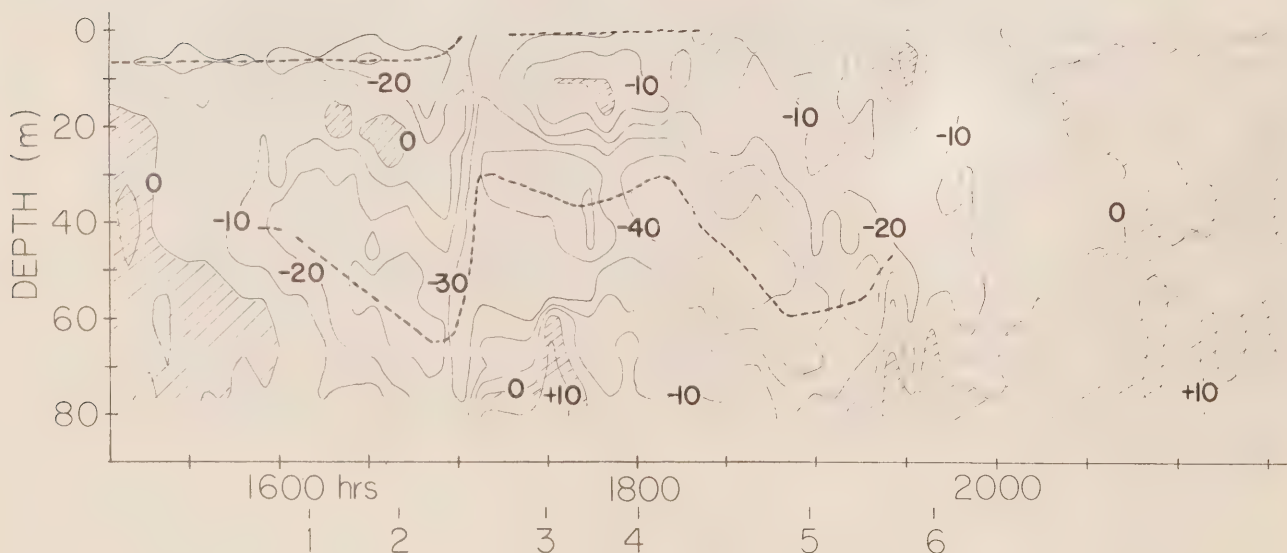
A two-week field program was undertaken in Knight Inlet as part of a study aimed at improving understanding of tidal interaction with a constriction and the way in which this influences circulation. It was found that under the right conditions, boundary layer separation at the crest of the sill can lead to a spreading mixing layer. This layer, which is often marked by well defined instabilities, achieves, a thickness of up to 50 m before collapsing. The formation of lee waves is closely linked to separation of the boundary layer, in much the same way as has recently been proposed for the atmospheric analogy of flow over mountains. Since the lee wave properties depend upon flow speed, a critical speed can occur at which the lee waves are able to suppress the separation. However, an important distinction in the case of tidal flow over sills is the acceleration of the current, which may be responsible for a strong asymmetry in the lee wave response that we have observed in Knight Inlet.

SALINITY CONTOURS



Contours of constant salinity (above) and along-channel velocity component (below) derived from profiles taken by Coastal Zone Oceanography, 300 m downstream of the sill in Knight Inlet during an ebb tide. The dashed line in the lower figure shows the location of the strong jet, which can change abruptly as lee waves escape upstream from the sill. Shaded areas correspond to reverse flow, toward the sill.

SPEED CONTOURS



Lighthouse Program, Task Force Studies and Saanich Inlet Program

The program for collection of daily sea-water samples from B.C. light stations continued, together with preparation of 1977 and 1978 data for publication. Advice was given on oceanographic aspects of various environmental problems including the proposed expansion of the Roberts Bank Terminal and modifications to the Sechelt Sewage System. Further editing was carried out on a Beaufort Sea report concerned with factors affecting pollutant dispersal.

Analysis of water properties in Saanich Inlet is providing further information on the flushing of this partly anoxic body of water. The dissolved oxygen contribution for 1978 indicates that below 100 m the water was not renewed in August/September as has generally occurred in other years. Apparently some renewal occurred between sill depth (80 m) and 150 m during July and November (1978). At sill depth during late 1978 there were net southerly flows (i.e. into the inlet) at monthly intervals, lasting about six days in each case.

Miscellaneous

Watching briefs were continued on developments in both mooring technology and ocean dumping technology. Development of a three-dimensional static sub-surface mooring model, as an aid in examining oceanographic data obtained from moored instruments, was completed. Assistance with mooring problems was provided to other groups in the Institute. A fourth review of an annual series of papers relation to the physics of ocean dumping was produced.

OCEAN MIXING SECTION

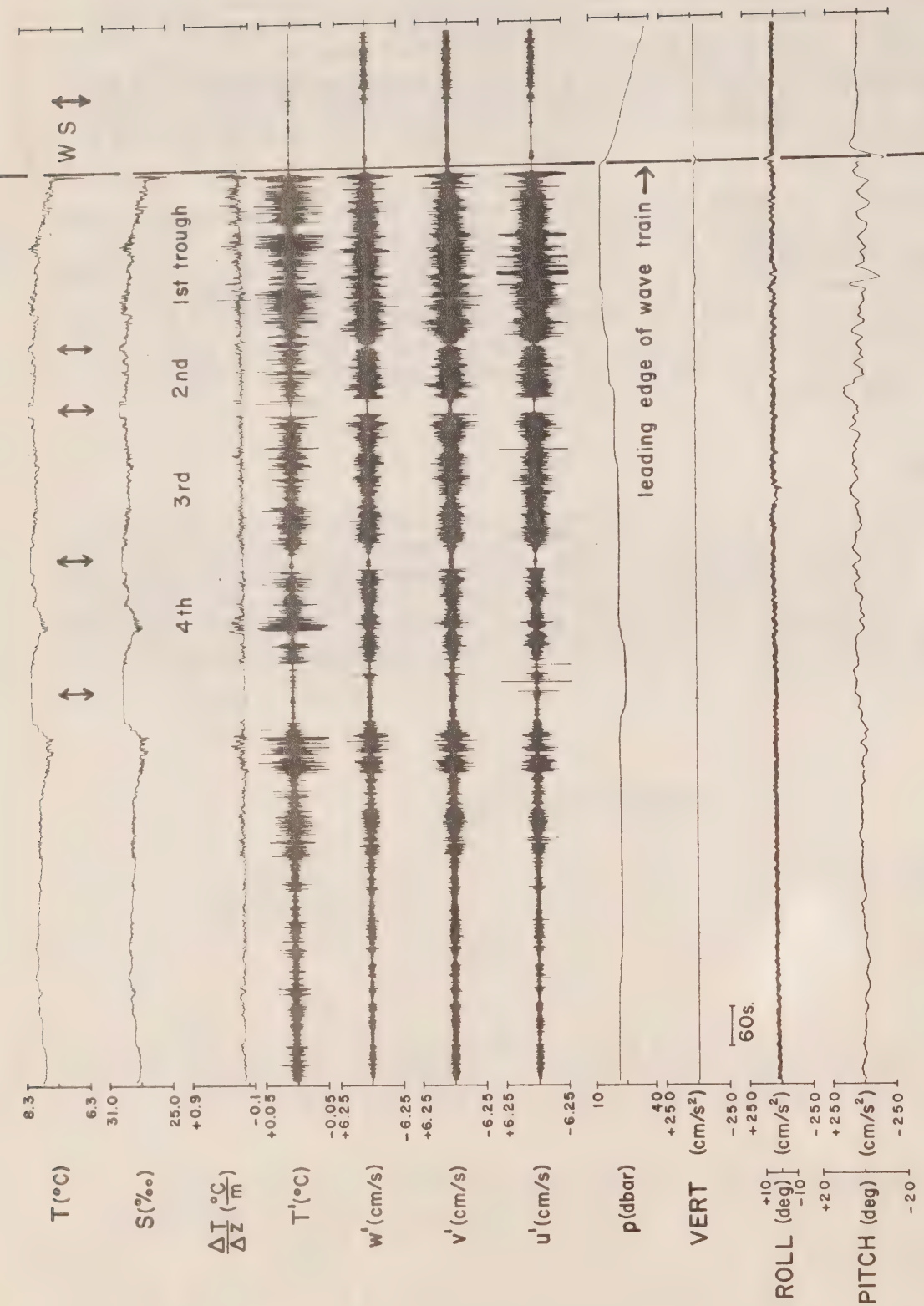
A.E. Gargett
*P.W. Nasmyth

G. Chase
R. Teichrob

*Left in 1979

The Ocean Mixing Group was incorporated into Offshore Oceanography during 1979, following the retirement of group head, Dr. P. Nasmyth; we shall miss Pat's smooth handling of our affairs and his cool head in times of crisis.

Considerable effort in 1979 went towards instrument calibration facilities. A calibrator built to fit the IOS water tunnel allows complete angle-of-attack calibrations of the small ducted rotor current meters used to measure forward speed and cross-flows on the *Pisces IV* submersible. Since the sensitivities of all high-frequency turbulence sensors are functions of mean flow speed, this is a particularly important measurement. A plume tank for calibration of the platinum film probes used for high frequency temperature measurements is near completion.



Records from *Pisces*-mounted turbulence package as the submersible passes through a train of highly turbulent internal waves. As *Pisces IV* travels from the rear (left) to the front of the wave train, the probes encounter warmer and saltier water (WS, marked by arrows) where internal wave crests lift the deeper water of the inlet up to the level of the submersible. Turbulent velocity (u' , v' , and w') and temperature (T') fluctuations are absent from these regions. Very strong downwelling velocities in front of the waves drive the submersible steadily deeper in the water column as soon as it passes through the leading edge of the wave train.

We are presently analysing the data obtained in Knight Inlet with the submersible-mounted turbulence package. Records from passage of *Pisces IV* through a highly turbulent train of non-linear internal waves are shown in the figure. As *Pisces IV* travels from the rear (left) to the front of the wave train, the probes encounter warmer and saltier water (WS, marked by arrows in the figure) where internal wave crests lift the deeper water of the inlet up to the level of the submersible: turbulent velocity (u' , v' and w') and temperature (T') in front of the waves drive the submersible steadily deeper in the water column as soon as it passes through the leading edge of the wave train.

OFFSHORE OCEANOGRAPHY

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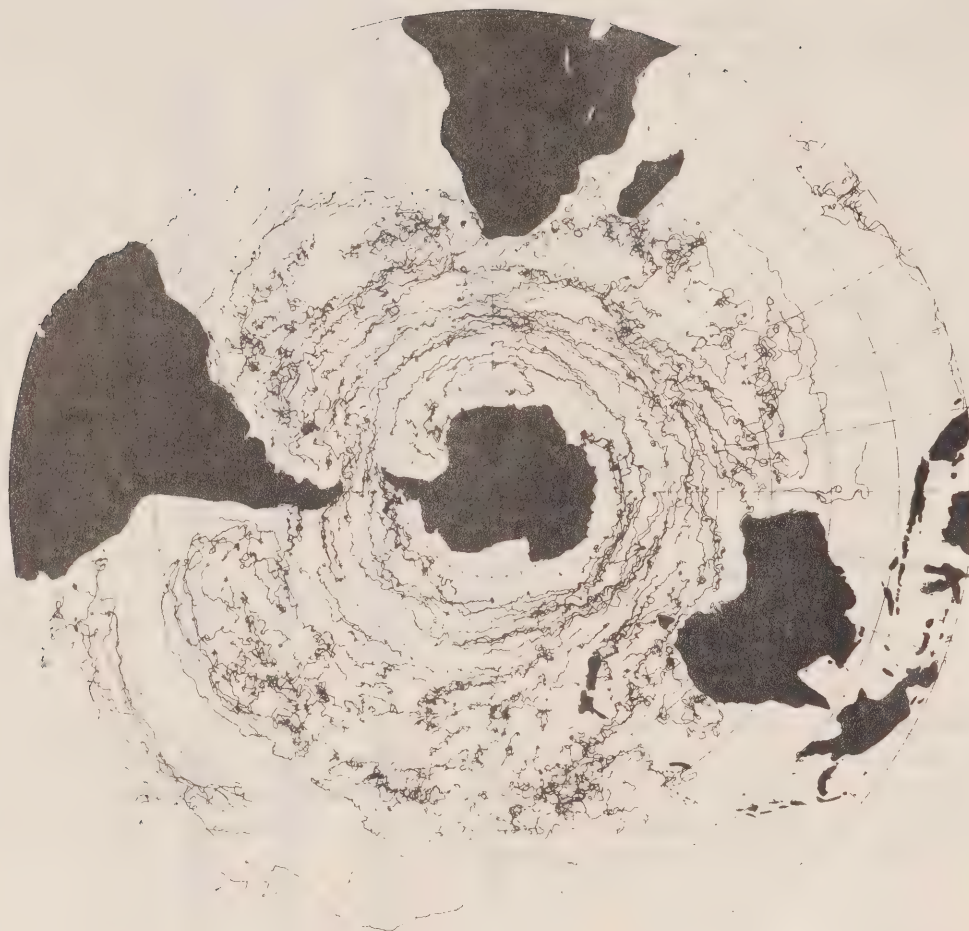
**Served as Section Head during part of 1979

During 1979 a major part of the efforts of the Offshore Oceanography Section was devoted to the First GARP Global Experiment. However this did not prevent significant participation in a new measurement programme on the continental shelf or of continuation of activities related to the weather ship programme and North Pacific oceanography.

FGGE Drifting Buoy System

Years of planning and preliminary work finally paid off with the successful implementation and operation of the Drifting Buoy System for the First GARP Global Experiment, (FGGE). The first of a total of 368 buoys was deployed in October 1978, while more than 200 were still working on November 30, 1979, the official end of the FGGE Observational Year. Most of the buoys were deployed in the southern hemisphere but there were also a number in the Arctic and in equatorial waters. The data from these buoys, which measured barometric pressure and sea surface temperature, were collected by the Argos system carried on the TIROS-N and NOAA-A satellites. This system also permitted determination of the position of each buoy several times daily, with an accuracy of about one kilometre.

The information recorded on the satellite was transmitted to one of several ground stations, which in turn relayed it to the Service Argos computer centre in Toulouse, France. There, the raw data were transformed into meteorological variables, and the buoy positions calculated. The resulting information was disseminated over the meteorological Global Telecommunications System, as well as being saved for future research use.



Tracks of drifting buoys deployed in the Southern Hemisphere during the FGGE Operational Year (December 1, 1978 - November 30, 1979). These buoys reported measurements of barometric pressure and sea surface temperature by means of the Argos Satellite and Data Collection System.

Preliminary results from the meteorological agencies using the buoy data indicate a need for significant revision of previous ideas on the severity and origins of high latitude storms. Several agencies reported a marked improvement in their ability to provide weather forecasts during the period the buoy data was available.

Canada, and IOS in particular, played an important part in the planning and implementation of this array. A prototype experiment conducted with Canadian buoys showed that the project was feasible. The complex plan for deployment of the buoy array using volunteer ships was developed by Dr. Noel Boston of Beak Consultants under contract to IOS. Canada contributed 74 buoys to the array. Dr. Garrett of IOS served as chairman of the Buoy Participants Committee which organized the project throughout its life. He also managed the Buoy Control Centre in Toulouse, which provided liaison between the buoy participants and the operators of the data collection system as well as the processing and quality control of the data stored for research use.

Coastal Oceanic Dynamics Experiment (CODE) (In conjunction with Tides and Currents, Ocean Ecology and Coastal Zone Oceanography Sections.)

Field operations for a major study of the oceanography off the west coast of Vancouver Island began in May with a three-week cruise on board the CSS *Parizeau*. Current meters were deployed on lines of moorings off Estevan Point and Brooks Peninsula, extending from the continental shelf to water depths of 2500 m roughly 150 km offshore, and at the entrance to Juan de Fuca Strait. Deep-sea and coastal tide gauges and two offshore anemometers were also installed as part of the program. The horizontal and spatial distribution of water properties (temperature, salinity, dissolved oxygen) in the region of the moorings were obtained for a grid of CTD/Hydro stations.

The CTD/Hydro measurements were repeated with greater detail during a two-week cruise in August using the *Pandora II*, and again in September when all current meters were refurbished.

Data collected during the 16-month field programme will provide oceanographers of the Institute of Ocean Sciences with a detailed knowledge of the spatial and temporal variability of currents, water properties and phytoplankton off the west coast of Vancouver Island. Physical processes to be studied include the generation and propagation of continental shelf waves and internal tides, seasonal variability of coastal currents and water structure, and upwelling events.

Vancouver Harbour Currents (In conjunction with Tides and Currents Section)

The First Narrows forms a confined, shallow (30 m) channel connecting the outer basin of Burrard Inlet to the inner basin (Vancouver Harbour) of the inlet. The channel possesses intense tidal currents of up to 2.5 m/s and seasonally varying vertical density structure of relevance to navigation. Cruises were undertaken on the CSS *Vector* in April, June and December 1978, during which time grids of 25-hour time-series current/CTD stations were occupied at the east and west approaches to the Narrows. Using acoustic

current meter/CTD profiles in conjunction with a shore-based trisponder ship-positioning system and an automatic data acquisition recorder, we were able to obtain "snap-shots" of water properties and horizontal currents over the two small spatial grids at the approaches to the Narrows. Despite the shallow depths, the currents show evidence of pronounced vertical shear at certain stages of the tide; there is also considerable small-scale horizontal eddy structure that can be used to advantage by operators of small vessels when entering the Narrows.

Johnstone Strait - Internal Tides (In conjunction with Tides and Currents Section)

The western basin of Johnstone Strait is a narrow deep channel separating northeastern Vancouver Island from the mainland coast. An analysis of current and water property measurements taken in the channel in 1973 and 1976-1978 showed that it possesses an internal (baroclinic) tide of semi-diurnal period generated through interaction of the surface tide with the shallow sill at the eastern end of the basin. Near the generation region, the baroclinic tide produces currents of over 20 cm/s, or 50% of the barotropic tidal currents, but accounts for less than 0.5% of the power lost by the barotropic tide in the vicinity of the sill. The baroclinic tide is dominated by a first-vertical mode, seaward propagating internal Kelvin wave which undergoes attenuation over an e-folding distance of one wavelength (25 km). Turbulent frictional effects account for attenuation of both the barotropic and baroclinic M_2 tides in the channel.

Seiches, Juan de Fuca Strait

A preliminary investigation was started into the cause of barotropic seiches in the larger embayments and inlets along the Canadian side of Juan de Fuca Strait. Pressure gauges deployed in Pedder Bay near Victoria for a period of two months in early 1978 gave spectral peaks at 10 and 15 minutes, with amplitudes of around 10 cm maximum. Further measurements are planned with pressure gauges in Victoria Harbour, Pedder Bay, Becher Bay and Port San Juan along the coast of Juan de Fuca.

Sea-Surface Temperature Anomalies Along Line P

Over the past 20 years continuous sea-surface temperatures have been observed along Line P by the two Canadian weatherships enroute to and from Station P. These data have finally been processed, edited and statistics compiled. From the climatic means and the associated standard deviations anomalies have been estimated. An example of the anomalies estimated for each cruise data for each month of 1979 is shown in the accompanying table. It is evident that during the first nine months positive anomalies were present over most of the Line except for near the coast where negative anomalies occurred during the first two months. In December the positive anomalies disappeared along most of the Line except near the coast.

		1979 ANOMALIES IN STANDARD DEVIATIONS																									
		145					140					135					130					125					LONG (°W)
JAN	1	5	5	4	3	4	5	5	5	3	3	2	2	2	2	0	0	0	-1	-4	-5	790105					
	3	5	4	5	4	3	5	5	5	3	2	4	2	2	3	2	0	0	0	-2	-4	-5	790107				
	15																										
	22																										
	29																										
FEB	5		4	4	4	2	5	2	4	5	3	2	1	1	2	1	1	0	0	-1	-3	-3	790209				
	12			5	4	2	3	2	4	5	2	2	0	1	2	0	1	0	0	-1	-2	-2	790211				
	19																										
	26																										
	5																										
MAR	12																										
	19	2	5	4	4	4	4	2	3	3	3	2	1	0			2	1	1	1	4	0	790323				
	26			4	4	4	5	2	3	3	3	2	1	0	1	1	1	1	0	1	2	0	790325				
	2																										
	9																										
APR	16																										
	23																										
	30	3	5	4	5	3	5	5	3	5	2	2	2	2	2	1	1	3	1	1	1	0	790504				
	7	5	5	4	5	3	5	2	5	5	1	1	1	1	2	1	1	1	1	0	0	1	790506				
	14																										
MAY	21																										
	28																										
	4																										
	11	3	2	5	4	3	2	5	3	5	2	2	3	2	2	3	3	3	2	1	0	0	790615				
	18			5	4	3	2	5	2	5	2	2	3	2	2	2	2	3	2	0	0	0	790617				
JUN	25																										
	2																										
	9																										
	16																										
	23	1	2	2	1	0	0	0	0	0	0	1	1	1	2	2	1	1	2	0	0		790727				
JUL	30	1	2	2	1	1	0	1	0	0	0	1	1	1	2	2	2	2	4	2	3	1	790729				
	6																										
	13																										
	20																										
	27																										
AUG	3	5	5	4	3	5	5	5	3	2	2	1	2	2	2	3	3	3	2	0	3		790907				
	10	5	5	4	3	3	5	5	3	2	2	2	2	1	2	2	3	3	3	3	2	2	790908				
	17																										
	24																										
	31																										
SEP	7																										
	14																										
	21																										
	28																										
	5																										
OCT	12																										
	19																										
	26	2	2	2	1	2	1	2	1	1	1	1	1	0	1	1	1	2	1	0	3	5	791019				
	31																						791021				
	7																										
NOV	14																										
	21																										
	28																										
	5																										
	12																										
DEC	19																										
	26	3	2	1	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	2	4	4	791202				
	31																										
	7																										
	14																										

Cruise I.D. 791202
Year
Month
Day

Cruise I.D.
Year
Month
Day

along Line P during 1979. The magnitudes of the observed temperatures are compared to the corresponding long-term averages (based on data taken usually over 20 years) by passing them through a step filter whose jumps are chosen from multiples of one half standard deviation ($\frac{\sigma}{2}$). "0" represents temperatures within $\pm\frac{\sigma}{2}$ of the long-term mean; "+1" indicates positive anomaly with value falling between $\frac{\sigma}{2}$ and σ ; similarly "2" represents positive anomaly with value falling between σ and $\frac{3\sigma}{2}$, etc.

Quality of Sea-surface Temperature Data

Knowledge of reliable sea-surface temperatures of the ocean is becoming increasingly important for understanding the influence of ocean temperatures upon weather and climate patterns (where even an anomaly of a few degrees of ocean temperature can affect these patterns), and for calibrating satellite observations of sea temperatures. For this reason, during the past few years a series of studies has been undertaken to examine the quality of sea-surface temperatures and salinities obtained in the northeast Pacific Ocean, from a number of platforms, including weatherships, research ships, anchored U.S. environmental buoys and merchant-naval ships, and employing a variety of instruments - ordinary bucket thermometers, specially-designed bucket thermometers, reversing thermometers, engine-intake temperature recorders, expendable bathythermographs (XBT), salinity-temperature-depth recorder (STD) and thermosalinographs. The results of most of these studies have already been reported. During the past year the remaining study was concerned with the difference between the accuracy of temperature measurements made by a specially-designed bucket thermometer and the engine-intake thermometer aboard the two weatherships CCGS *Quadra* and *Vancouver*. This study was required to clarify a controversy surrounding the relative merits of the two main methods of sea-surface temperature observations used routinely by merchant-naval ships. The results indicated that the mean difference between the bucket and engine-intake temperatures and the associated standard deviation for data from *Quadra* were both small, (a mean difference smaller than 0.1°C and a standard deviation also less than $\pm 0.1^{\circ}\text{C}$) and consistent during the first five cruises over the one year period. For subsequent cruises both the mean difference and standard deviation varied considerably. It was concluded that the engine-intake thermometer requires calibration at least once a year in order to maintain the quality of the data. The mean difference and the associated standard deviation for data from the *Vancouver*, on the other hand, both fluctuated appreciably from one cruise to another. This is attributed to a faulty measuring system aboard this ship. The study further indicated that the engine-intake method can indeed provide reliable sea-surface temperatures that are as accurate as those obtained by the use of specially-designed thermometers, provided that an upper mixed layer exists when measurements are made.

Satellite Derived Surface Sea-temperature off B.C. Coast

Infrared satellite imagery of the waters off the Pacific coast of Canada for the five-year period (July 1974 through July 1979) have been examined in order to delineate sea-surface temperature patterns in the area. A series of charts depicting oceanic thermal fronts has been compiled. The source data consists of enhanced infrared imagery in photographic-print format, obtained mostly from the National Satellite Services Branch of National Climatic Center (NOAA), some from its San Francisco Field Station and also some from the Arctic Weather Centre of the Atmospheric Environment Service of Canada. With regularly obtained imagery in print format, only two shades of the grey-tone variations of the sea surface can be delineated successfully by an optical device. However, with suitably-enhanced imagery made from original data that is processed locally, at least six shades of these variations can be differentiated. The imagery has been found useful to explain the occurrence of certain water types and has provided better insight into the detailed circulation off our coast.



The figure illustrates an example of very high resolution radiometer (VHRR) NOAA-5 infrared imagery of Western Canada and the USA, including the waters off the Pacific coast, based upon data taken during the daytime overpass at 22:34 GMT, 14 July 1979. Light and dark tones represent lower and higher temperatures, respectively. The coldest oceanic waters occur in Juan de Fuca Strait and Queen Charlotte Strait, while the warmest waters are found off the coast of Washington and Oregon. The well-defined tongue of cold water lying offshore of Juan de Fuca Strait, with source water along the west coast of central Vancouver Island, may be associated with the southward flow of coastal water.

Ocean Response Study

IOS participation in the Anomaly Dynamics Study of NORPAX is aimed at resolving the mechanisms responsible for the evolution of the thermal structure of the upper 300 metres of the open ocean. AXBT surveys of the North Pacific between 50°N to 40°N in the vicinity of 170°W, have been conducted on a bi-weekly basis for the period extending from March 1977 until April 1979.

Seasonal changes and interannual variation in the heat content were assessed at various latitudes. From a combination of this data and information about the horizontal gradients, it is possible to assess the importance of one dimensional processes in relation to advective processes. From this study it is clear that advective processes are a major factor in creating both the interannual variations and other events occurring below the mixed layer to the 150 metre level.

During the current year, further progress was also made towards participation in the "ship-of-opportunity program" of NORPAX. Expendable CTD systems have been evaluated and they are ready for use in combination with surface salinity and temperature sensors.

NUMERICAL MODELLING SECTION

R. F. Henry - Head

P.B. Crean

M.G.G. Foreman (Computing Services)

T.S. Murty

P.J. Richards

The Numerical Modelling Section continues involvement in the development and application of numerical modelling methods for simulation of oceanographic problems, in cooperation with other groups.

A time-dependent two-layer hydrostatic numerical model, to simulate internal surges or internal hydraulic jumps, was completed and applied successfully to Babine Lake and to a laboratory tank. Then, a more sophisticated model under the triple-deck approximation was developed which allowed partially for non-hydrostatic pressure effects and continuous density stratification. The most important feature of the triple deck model is that it permits separation of the flow on the downstream side of the sill. This model was successfully tested both for the natural scale as well as for the laboratory scale.

Preliminary work using analytical models was completed on the problem of nonlinear interaction between storm surges and astronomical tides.

Collaboration with NOAA and the University of Hawaii continued on two major tsunami projects. The first involved the development of a new objective scale for tsunami magnitude; the second involved numerical simulation of lateral waves with the goal of identifying them in tsunami records.

The manuscript of a comprehensive book on storm surges was completed.

Studies were begun of tidally-generated residual circulation. A linear model was developed and tested for the St. Lawrence estuary and work is in progress on nonlinear models of the same area and of Bridport Inlet on Melville Island.

Transmission of internal Kelvin waves in fjords was studied using a variety of methods. This led to a significant revision of a popular finite difference method for the shallow water equations. A barotropic ocean circulation model with negative eddy viscosity was completed.

A program for tidal constituent analysis based on high and low water observations was developed in order to process observations collected in the Arctic by the oil industry. The program permits analysis of records with missing data and inference of constituents.

Programs developed during the last two years for tidal height and current analyses were supplied to a number of researchers in Canada and abroad. The relevant manuals were revised and reprinted. Mike Foreman was invited to the University of Hawaii to install the tidal analysis package and advise on its use.

Numerical model studies of the Georgia/Fuca system in 1979 have primarily been concerned with exploratory stratified flow simulations and analyses of earlier barotropic tidal model output.

The object of the numerical experiments on stratified flow is to find a viable means of simulating the estuarine circulation in a topographically complex deep coastal sea subject to strong tidal mixing when the time scales of important changes on the open boundaries require extended model runs. Using a laterally integrated two-dimensional numerical scheme (x, z, t , dependent), mixed tidal co-oscillations have been simulated for the homogenous fluid case in a gulf of variable width and depth approximating the main channels. Encouraging initial results have been obtained in which internal seiche motions and associated mixing in a stratified rectangular basin, of dimensions approximating those of the Georgia/Fuca system, have been simulated using both free surface and the less expensive "rigid lid" approximation.

Analyses of the output of the coarse grid and fine grid barotropic tidal models have been undertaken by a private firm of consultants. These include harmonic analyses and predictions of the tides and currents, together with energy volume flux and residual flow calculations. The residual barotropic tidal circulation obtained from a one month run of the fine grid model clearly shows the effects of the major topographically induced eddies in the tidal streams.

It appears probable that a proposal to continue work on the upper layer buoyant spreading model of the Fraser River plume, by the same firm, will be funded. An extensive field program is included, which would involve cooperation of the Canadian Coast Guard.

Field operations during the year included further drogue tracking exercises, which verified the existence of the large tidal eddies that give rise to marked residual circulation, and observations on the shallow banks near the mouth of the Fraser River. Together with earlier observations, the latter have provided a plausible qualitative dynamical explanation of the effects of the tidal changes in elevation in the adjacent strait on the discharge pattern at the river mouth.

REMOTE SENSING SECTION

J.F.R. Gower - Head

J.S. Wallace

The Remote Sensing Section has responsibility for development of aircraft and satellite remote sensing techniques for oceanography, and for evaluation of techniques originating elsewhere.

Even though its useful life was limited to four months during the summer of 1978, the oceanographic satellite, SEASAT A, provided enough data to keep the scientists who were involved with the program, occupied throughout 1979. J.F.R. Gower is a principal investigator in three experiments studying synthetic aperture radar (SAR) imaging of roughness patterns due to internal waves, ocean waves and ocean current systems respectively.

The first experiment was organized jointly with B. Hughes of the Defence Research Establishment Pacific and involved very precise measurements of sea surface roughness properties during a SEASAT overpass. A laser surface slope meter was deployed by the CNAV *Endeavour* over internal wave patterns in Georgia Strait, north of Boundary Pass. The resulting surface roughness patterns were also imaged by the SAR on the Canadian Sursat aircraft. The aircraft and satellite data arrived slowly during 1979 and is being analysed to show how SAR's respond to surface roughness viewed at different angles and with different wavelengths, polarizations and resolution.

The second experiment represents the major U.S. NASA/NOAA check on accuracy of the SEASAT SAR for measuring ocean waves. Canadian participation consisted of providing data from ocean Station PAPA, from the Tofino wave-rider station and arranging flights with the SAR over the experiment sites to give more radar data than would result from SEASAT alone.

The third experiment is being conducted with P. LaViolette of the U.S. Navy NORDA in Mississippi and is designed to study imaging surface roughness changes induced by the thermal or dynamic effects of the Gulf Stream near the tail of the Grand Banks. The second field phase of the experiment met with limited success in June 1979 when bad weather held the ship back from the experiment area. Flights out of St. John's resulted in excellent thermal maps with current measurements and airborne laser surface roughness data. Although this phase took place after SEASAT's breakdown it showed the strong boundary layer modulation induced by the current, and will allow interpretation of the other aircraft and satellite radar data taken during the experiment.

Results from all three experiments have appeared in publications and reports, but as more sophisticated processing of the SEASAT SAR data continues, further conclusions can be made. In fact as the processing techniques for this type of radar become better understood and more widely available, it appears that high resolution mapping radar may one day be a standard sensor in space.

The joint Canada France Ocean Optics Experiment (CFOX) resulted in major field work during 1979. The purpose of this experiment was to bring together our airborne spectroscopic measurements of water colour with similar work and underwater optical measurements being made by A. Morel's group of the University of Paris. Joint operations were carried out (a) in the Ligurian Sea south of Monte Carlo (PROLIFIC) in March with a French DC-3 and French and Italian ships, (b) in B.C. coastal waters using the CFAV *Endeavour* and CSS *Vector* with a locally chartered aircraft in July and (c) in the Eastern Canadian Arctic in August using the chartered vessel *Theron* and chartered aircraft flying out of Pond Inlet and Resolute Bay. PetroCanada Ltd. and the Polar Continental Shelf Project supported this Arctic operation.

This has led to several improvements in processing of the airborne spectroscopic data which in turn allows generation of improved maps of chlorophyll concentration in Lancaster Sound and Western Baffin Bay. Data from NASA's Coastal Zone Colour Scanner flown on Nimbus 7 was collected for all of the above areas but has not yet come available through their overloaded data processing system.

Other chlorophyll mapping flights were made along the B.C. Coast by Seakem Oceanography Ltd. as part of an experimental survey with a ship of opportunity. Data from these flights has also added to our understanding of chlorophyll distribution and the problems of mapping it from the air.

OCEAN CHEMISTRY DIVISION

C.S. Wong - Head of Division

R.D. Bellegay
W.J. Cretney
*K. Iseki
W.K. Johnson
D.M. Macdonald
R.W. Macdonald
F.A. McLaughlin

P.S. Munro
J.S. Page (Computing Services)
D.W. Paton
T.J. Soutar
*V. Stukas
J.A.J. Thompson
F.A. Whitney

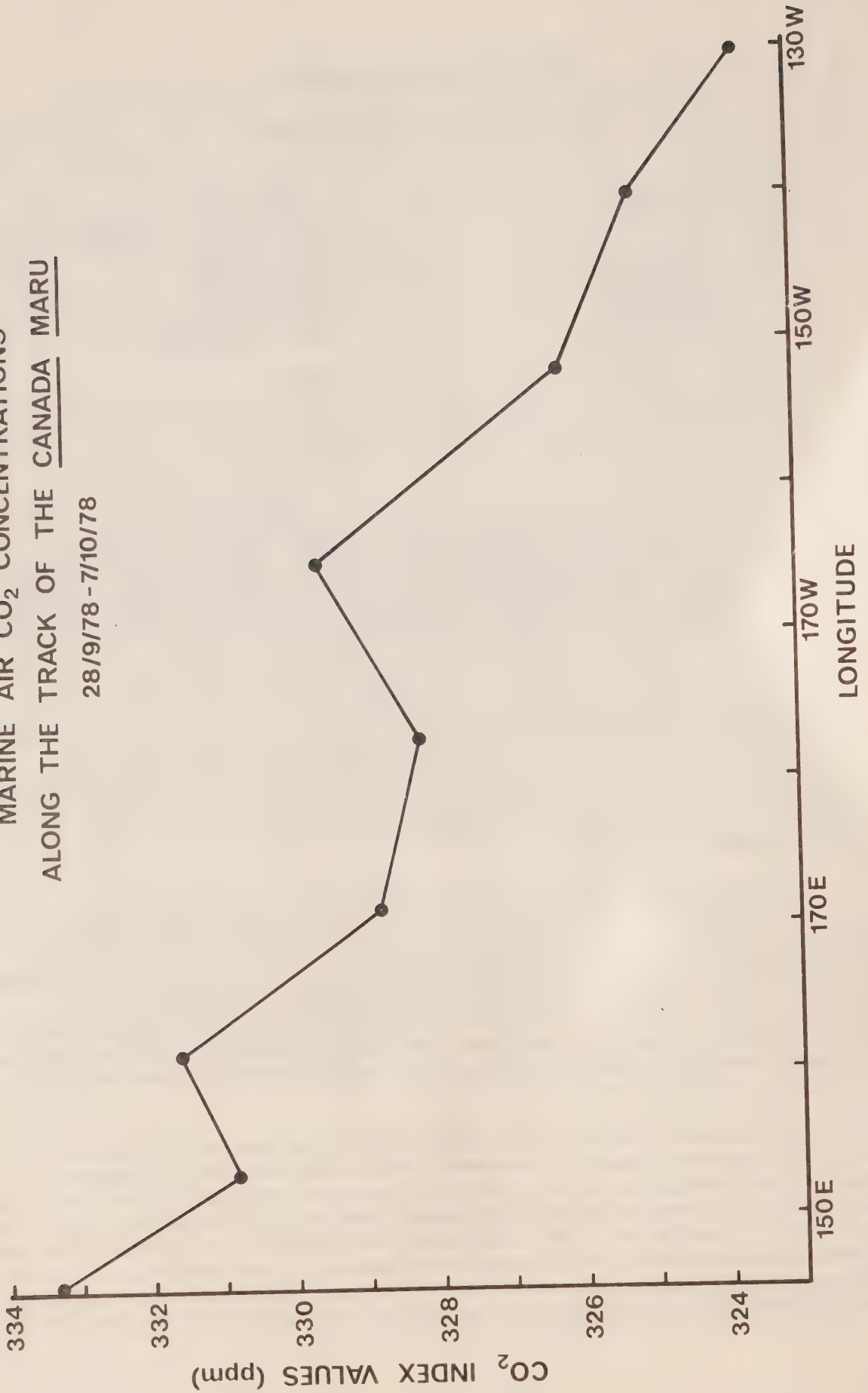
*Left in 1979

The primary responsibility of the Ocean Chemistry Division is to provide expertise and advice in the chemical aspects of the marine environment in B.C. coastal waters, the western Arctic and N.E. Pacific Ocean; to conduct the necessary research and monitoring activities at the regional, national and/or international level in order to contribute to policy, legislation and scientific knowledge and in particular to provide an understanding of the chemical effects of human activities on the ocean, its suspended matter and bottom sediments, and the effect of the ocean on man's activities. These effects must be distinguished from natural and often non-systematic variations thereby requiring long-term and sustained research effort. A secondary role is to understand the interaction of the inorganic and organic material with the marine biota and geological reservoirs in order to provide chemical oceanographic information including chemical uptake-release processes that are useful in fisheries research, in geological studies and in investigations of water transport and mixing.

Through active support of the Federal Government Make-or-Buy policy, the Division has achieved the goal of establishing a viable and credible capability in private industry on the west coast. Industry is now able to conduct chemical oceanographic studies related to ocean dumping, environmental contaminants, oil pollution and environmental impact assessment of mine tailings disposal, arctic drilling and industrial activities. These short-term, site-specific studies which are frequently of immediate concern to the public, will continue to be pursued mainly via the contract route under the supervision of the Division.

The in-house effort is directed towards pursuit of the longer-term but equally important research problems. These include the influence of oceanic carbon dioxide (CO₂) on climate and chemical variability in the ocean. Often, unique and expensive facilities are required, for example, ultra-clean laboratories for analysing trace metals and hydrocarbons, a heavy-isotope mass spectrometer for accurate trace metal measurements, a gas chromatograph/mass spectrometer/data system for identification of oil and chlorinated compounds and an infrared CO₂ calibration and analytical laboratory for CO₂ geophysical

MARINE AIR CO₂ CONCENTRATIONS
ALONG THE TRACK OF THE CANADA MARU
28/9/78 - 7/10/78



time-series studies. These facilities enable us to maintain a state-of-the-art capability in ocean chemistry, with sufficient scientific capability to supervise contracts, scrutinize work performed by the private sector and to provide the necessary scientific expertise to advise policy-makers in an effective way.

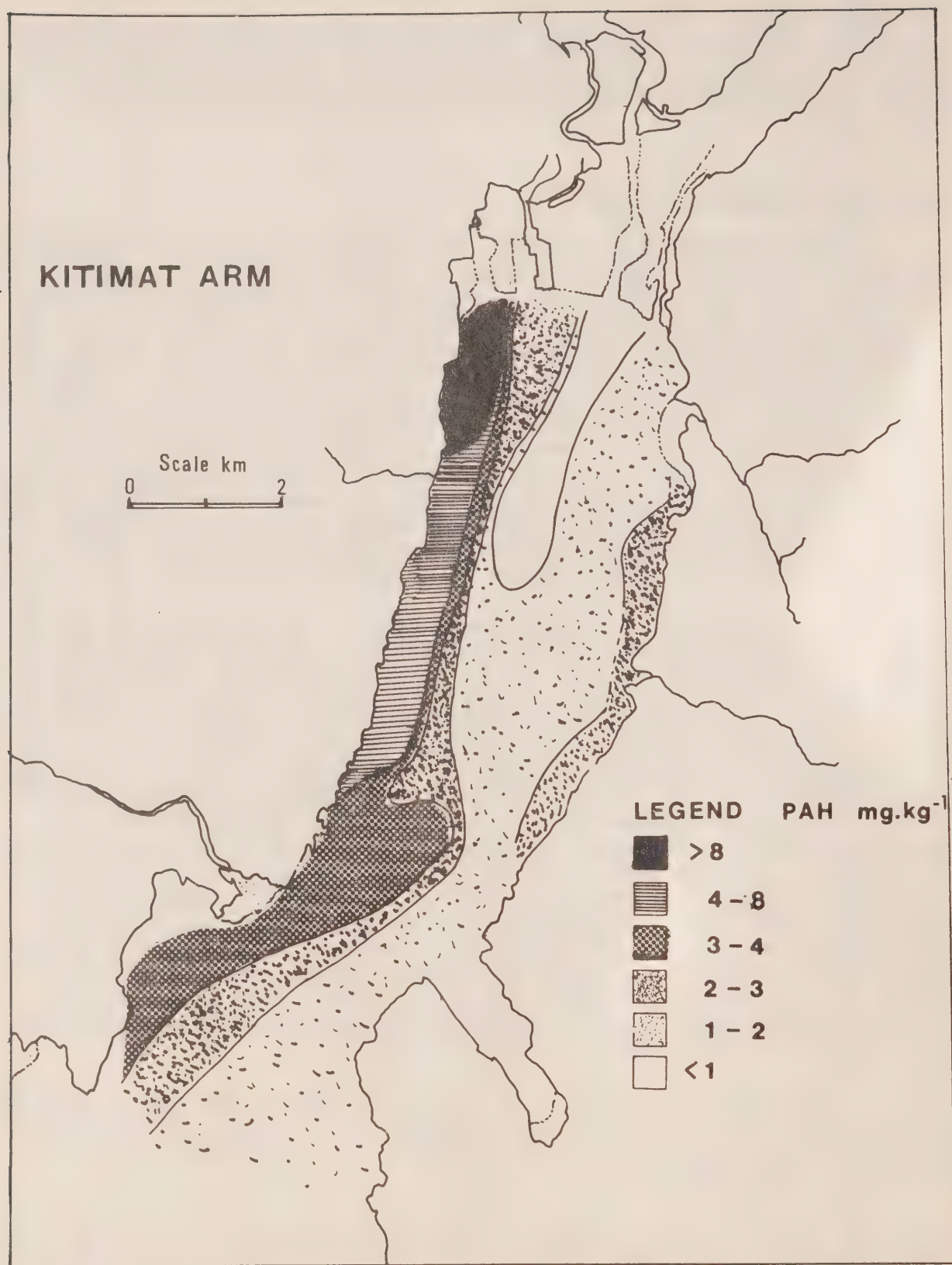
Marine Carbon Research Centre

CO₂ has emerged as a leading environmental problem that will remain with us well into the future. The ocean is expected to play the most important role as the major sink for CO₂ released into the atmosphere through fossil-fuel burning. Over a few hundred years it is expected to absorb five to eight times the present atmospheric level of CO₂. There is a great uncertainty in knowledge of marine CO₂ variability and pathways. To tackle this difficult and long-term problem, a marine carbon research centre was created to focus our national and international marine CO₂ activities, to collect multi-disciplinary information for synthesizing a coherent picture of the complex marine carbon cycle, to provide a uniform, long-term analysis and inter-comparison of Canadian CO₂ data and to disseminate CO₂ data through publication of geophysical and geochemical monitoring time series. This centre complements the AES Climate Centre where a major effort is directed towards modelling the climatic effects of fossil fuel derived CO₂.

The CO₂ problem is international. All of us contribute to the atmospheric CO₂ increase by burning oil and coal to keep our houses warm and to keep our civilization moving. The research problem is so immense that it must be solved collectively by generations of teams of scientific workers - each team contributing knowledge to only a few aspects of what is a global problem. Our contribution has been directed towards collecting and interpreting time-series measurements of CO₂ over the ocean. This year marks the tenth anniversary of the CO₂ time-series at Ocean Weather Station P (50°N, 145°W). However any celebration was overshadowed by the possibility of termination of the weatherships in the near future. Two replacement programs are under way: one involves weekly collection of atmospheric CO₂ samples at lighthouses at Amphitrite Point, Kains Island and Cape St. James, on the west coast of Vancouver Island and Queen Charlotte Islands, and the other involves "ship of opportunity" collection of air and oceanic samples by the *Canada Maru* en route across the Pacific Ocean. Preliminary results from Pacific Ocean transects indicated very large spatial variations in marine air CO₂ concentrations as well as seasonal fluctuations. A long time-series would be required for effective data interpretation.

In addition to Station P analysis, our infrared laboratory has been performing air CO₂ analysis for other Canadian CO₂ stations at Sable Island in the Atlantic and at Alert in the Canadian Arctic, both manned by the Atmospheric Environment Service.

Observations of atmospheric and oceanic CO₂ were made during the First GARP Global Experiment (FGGE) cruise of the *Parizeau*, December 28, 1978 to March 3, 1979 between Victoria and 2°S, 150°W. Air and sea water samples for CO₂, ¹³C and radiocarbon, nutrients and carbonate chemistry were collected. Continuous CO₂ partial pressure measurements indicated a super-saturation of



Concentrations of PAH (Polycyclic aromatic hydrocarbons) in the surface sediment in Kitimat Arm, an environmentally sensitive area along the northwest British Columbia coast.

CO₂ up to 80×10^{-6} parts per million of volume in the equatorial waters with respect to atmospheric levels, according to the preliminary data. Checks will be made on the calibration and previous work by Scripps Institution of Oceanography in the area to see if an increase in pCO₂ in seawater is observable.

The last of a long series of CEPEX controlled experiments was performed in Saanich Inlet from June 2 to July 5, 1979. The study concentrated on heterotrophic transfer of carbon in the utilization of glucose enrichment in controlled systems, an idea initiated by Professor T.R. Parsons of the Department of Oceanography, University of British Columbia (UBC). The work was carried out as a co-operative project with UBC, Simon Fraser University and Southampton University in the U.K. Carbon fourteen-labelled D-glucose was added to plastic enclosures containing 65,000 liters of seawater to produce glucose enrichments of 1 mg/L and 5 mg/L. Observations of nutrients, pH, O₂, chlorophyll *a*, primary production, carbonate chemistry, particulate organic carbon, dissolved organic carbon, phytoplankton, zooplankton, bacteria and other environmental parameters such as light intensity, particle-size distribution, temperature and salinity were made. Excess glucose tended to suppress photosynthetic activities in the enclosures which also exhibited high removal of dissolved oxygen. There was a large increase in bacterial biomass in the 5 mg/L bag. From the ¹⁴C-labelled experiment, it was determined that approximately 13% of the particulate carbon remained while 87% of the glucose was remineralized to CO₂.

Marine Hydrocarbons - Kitimat Baseline

The general objective of this program is to understand the occurrence, pathways and fate of hydrocarbons (natural, petroleum, PCBs and pesticides) in the marine environment. The main emphasis in 1979 was placed on an environmental baseline study at the Kitimat Harbour and its approaches.

Kitimat, which has been proposed as a possible oil port site to receive Alaskan crude for trans-shipment, is located at the head of an environmentally sensitive fjord system. Future industrial growth is also expected to be high in this northwestern B.C. coastal region. A baseline study, submitted as an unsolicited proposal by Seakem Oceanography Ltd., was performed under Ocean Chemistry Division supervision. A series of cruises on chartered vessels was conducted. Those in 1979 included a February 5-16 cruise to collect samples of sea water, marine organisms and sediments for baseline hydrocarbons and nutrient study, together with background chemical oceanographic data, an April 8-13 cruise mainly to collect mussels and clam samples for histopathological analysis, and a July 22-26 charter cruise to Port Alberni to collect samples for estimation of polyaromatic hydrocarbon levels in sediments and inter-tidal mussels.

It is not easy to establish the baseline conditions in the Kitimat area. The marine environment is continually being subjected to input from aluminum plant and pulp mill effluents. It is equally difficult to interpret the relationship between levels of polyaromatic hydrocarbons (PAH) measured with the physiological disorders observed in marine bivalve mollusks collected in the area. Thus, collection of similar organisms was made in an area already known to be polluted by pulp mill effluents near Port Alberni.

Preliminary results showed a highly variable level of polyaromatic hydrocarbons in the tissues of mussels from the western side of Kitimat harbour. However, a statistical correlation was found between the sediment levels of PAH and the incidence of a particular proliferative cellular disorder in mussels and clams from the Kitimat area.

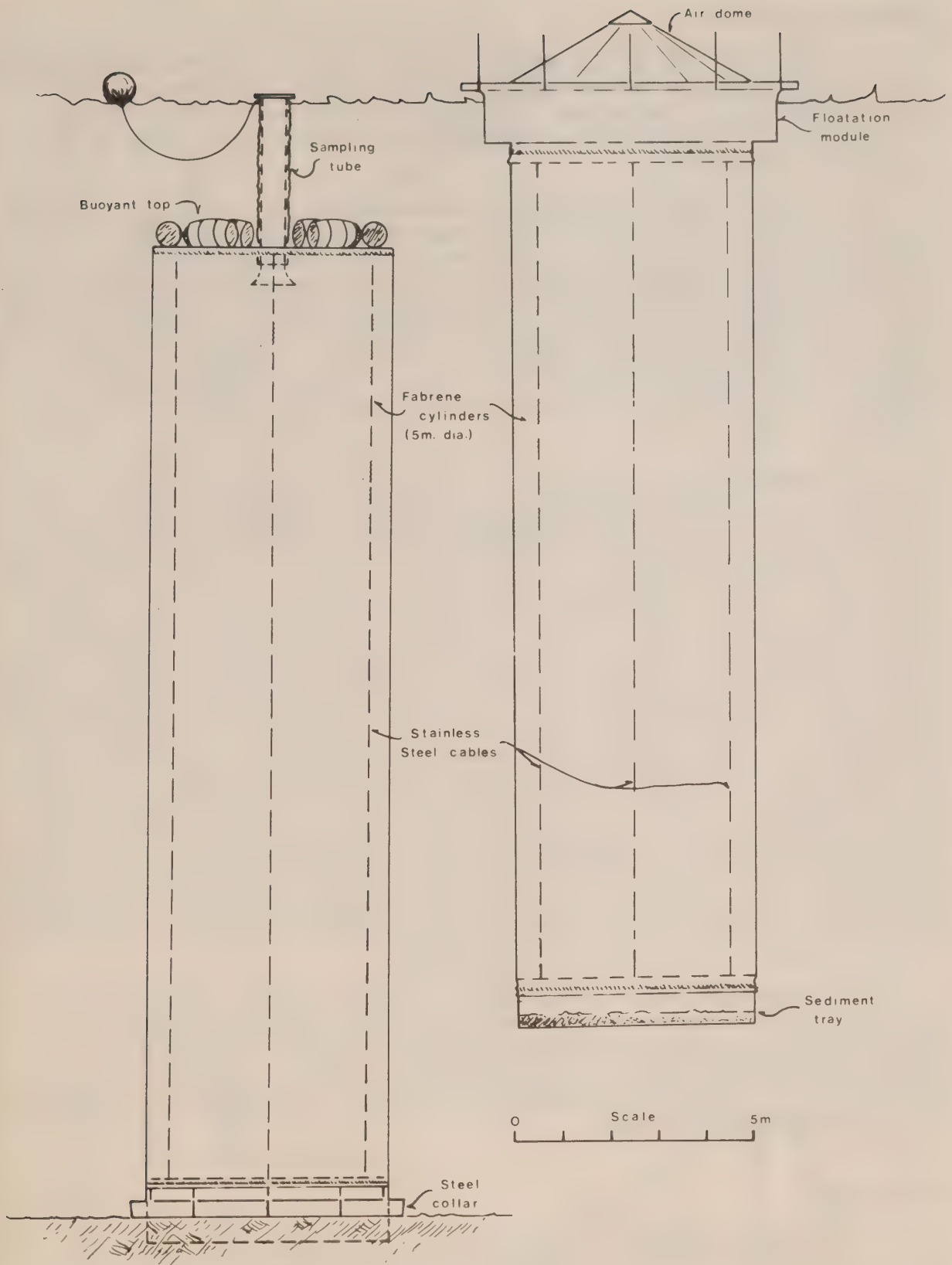
As in the case of trace metals, a unique clean room has been established for hydrocarbons. The major facility, a gas chromatograph/mass spectrometer system was upgraded with the acquisition of a Finnigan INCOS MS data system. This enables the group to perform multiple ion detection, display the spectra and compare the data to an extensive library of compounds as well as interfacing to other INCOS/systems in the nation. A library of compounds is being established to serve as an identification centre for petroleum and other hydrocarbons in the marine environment of the western coast.

Supported by Ocean Dumping funds, a study was made of the variability of PCB contaminants in dredged spoils to examine the reliability of sampling and analysis techniques for use under the Ocean Dumping Act. Replicate sampling of mud was carried out in Victoria Harbour prior to dredging, and in several barges loaded with dredge spoil destined for ocean disposal. Analysis of variance was applied in order to determine where significant variations were occurring, and how best to sample to obtain reliable but inexpensive information. For example, adequate sampling prior to dredging in a new area could reduce monitoring required later at the dumpsite.

Chemical Controlled Experiments

CEPEX (Controlled Ecosystem Pollution Enclosure Experiments), with the original objective to study pollution stresses on natural plankton populations was terminated in 1979 by National Science Foundation in the U.S.A. The facilities installed in Saanich Inlet near the site of the Institute of Ocean Sciences, including large and small floats and bag systems, were officially transferred to the Ocean Chemistry Division for future chemical studies, and for herring experiments by fisheries scientists.

A new system, CHEMCELL, which includes the additional dimension of the sediment/water interface is being developed and constructed via an unsolicited proposal by C.E.L.L. at Victoria under the scientific authority of Ocean Chemistry Division. The new system consists of a flexible plastic bag attached by a steel collar to the bottom in Saanich Inlet at one end and a dome system to enclose an atmosphere at the other end. An international SEAFLUXES program to study the air-sea boundary fluxes and the seawater/sediment boundary interaction is being consolidated. Tentatively, it will involve Ocean Chemistry Division, the Department of Oceanography at UBC, and the Institut für Meereskunde at Kiel, F.R. Germany, the Institute of Biological Sciences & Environmental Sciences at the University of Tsukuba in Japan, individual scientists from U.S.A. and France as well as the Quebec Region of Fisheries and Oceans.



Designs of the CHEMCELL Experimental Systems for chemical controlled experiments under the SEAFLUXES program to be conducted in Saanich Inlet near the Institute of Ocean Sciences.

Coastal Pollution

Mining is one of the major industries in B.C. Its tailings disposal is of great concern to the environment departments of the provincial and federal governments. Pollution from sewage outfalls is of major concern to the public and municipalities. These studies form the main thrust of the coastal pollution program.

Emphasis has been placed on understanding the levels and trends of heavy metals in marine organisms in polluted areas, determining the mechanisms of transformation of these metals into toxic forms, as well as detoxification mechanisms operating within marine organisms. The heavy metals copper, zinc and cadmium in the holothurian *Molpadia intermedia* were studied to determine the suitability of using this as a possible monitoring organism for the Point Grey Dumpsite. No significant differences were observed when compared to those from a control area. A similar study is underway for marine organisms collected near the Macaulay outfall area in Victoria.

Methylation of heavy metals in the marine environment is not well understood. For example, mercury can be methylated by marine organisms and bacteria into the more toxic methylmercury forms of CH_3Hg^+ and $(\text{CH}_3)_2\text{Hg}$. To understand similar processes for several other metals introduced by dumping of mine tailings into the marine environment, contract research was conducted on lead and arsenic. Funded by Ocean Dumping funds, a contract was awarded to Beak Consultants Ltd. for study of the methylation of lead in sediment samples from Burrard Inlet, Goletas Channel, Granby Bay where there is an abandoned copper mine and Alice Arm where inactive molybdenum mines have historically disposed of high-lead content tailings. Results indicated that discharge of lead-bearing particulates did not appear subject to mobilization of lead by methylation under anoxic conditions. A study of the methylation of arsenic in marine sediments and interstitial waters in Rupert Inlet, B.C. was pursued under contract to Beak Consultants Ltd. using sediment samples from areas polluted by copper mine tailings. Results suggested that arsenic did not appear to pose a significant hazard. No arsenic species were detected in sea water while in the interstitial waters, total inorganic arsenic varied between 3.5-4.9 $\mu\text{g/L}$ possibly correlated with tailings loading. Incubation of sediments with nutrients indicated that the degree of arsenic methylation depended primarily upon arsenic availability.

Organotins were designated as a class of contaminants of high priority in the Environmental Contaminants list. Under Environmental Contaminants Act funding a contract is underway with Dr. Cullen of UBC to develop analytical procedures for organotins in order to investigate the occurrence, and nature of tin compounds in sewage and industrial effluents in both fresh and marine waters.

Trace Metals

The main objective of the program is to assess the natural and anthropogenic inputs of physiologically significant trace metals into the marine environment and their interaction with suspended matter, the planktonic biota and surface sediments.



Isopleths indicating copper concentrations in marine sediments in $\mu\text{g g}^{-1}$ (dry weight) in the vicinity of Texada Mine near the central part of Georgia Strait, B.C.

The trace metals work is directed towards several major long-term efforts. The first is to assess the gap in knowledge between marine chemists engaged in attaining meaningful levels of trace metals in seawater and those working on modelling of chemical speciation and biological effects of trace metals. A NATO-funded organizing committee with this direction was held at Ocean Chemistry Division, which received a NATO grant to organize an Advanced Research Institute in Europe in 1980/81 to summarize the state-of-the-art on accurate measurements of trace metals in sea water and research directions. The second objective is the continuation of long-term work on accurate measurements of trace metals by using ultra-clean laboratory techniques coupled with mass spectrometer and other instrumentation, with the plan to develop a "standard sea water" with concentrations near to natural levels in open ocean. This year's work involved confirmation of the state of cleanliness of the ultra-clean laboratory, measurements showing a hundredfold reduction of metals being atmospherically transported in a normal laboratory. A long-term storage test on lead, mercury, cadmium, zinc, copper, nickel, cobalt and iron in seawater is underway. The third objective is to understand and model the flux of metals between and accumulation of metals within the important environmental compartments; sea water, marine biota and surface sediment. This problem is being addressed through a five-year SEAFLEXES program (Sediment/ecosystem/atmosphere flux enclosure study). The present phase is the construction of the experimental system being carried out through a \$270,000 unsolicited proposal, previously described under Controlled Experiment.

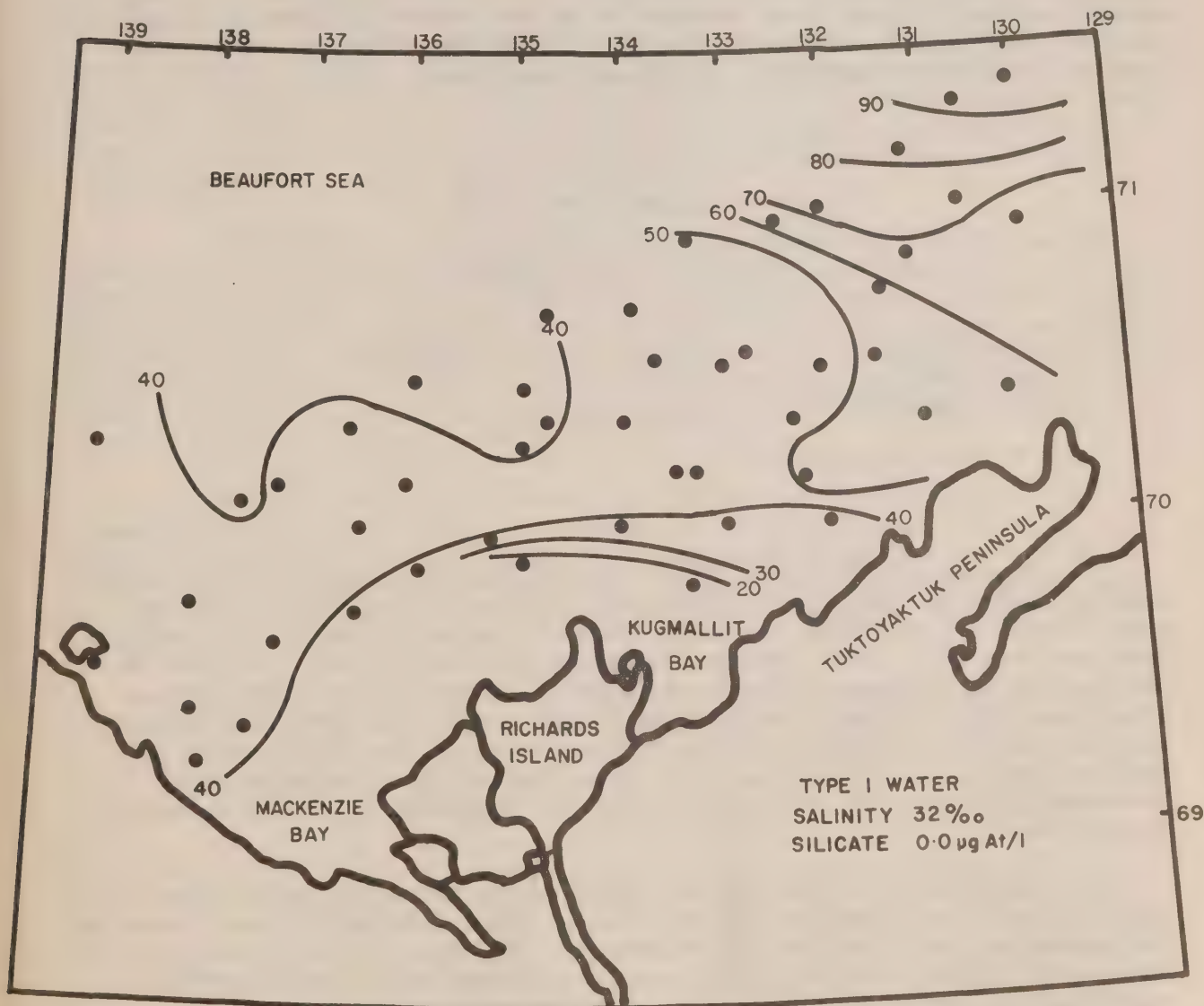
For ocean dumping work, research through contract is being carried out on a selective extraction scheme for trace metals for marine sediment and dumped material so as to improve the effectiveness of regulations. Two cores were collected; one each from Victoria Harbour and False Creek and subsamples were subjected to the ultrate test as well as an extraction scheme to separate metals into the different chemical fractions of (1) interstitial water, (2) exchangeable, (3) easily reducible, (4) oxidizable, (5) moderately reducible and (6) residual. Results showed that the largest metal reservoirs were in general the oxidizable and the residual compartments but mercury, an exception, was located in the residual phase mainly. Results of the release experiments carried out at low particulate levels in seawater showed that residual Hg was not mobile. There was evidence, however that about 50% of the Cd was mobilized.

The time-scale of natural sedimentation and metal loadings due to mining activity near a lake in the Kootenay area of B.C. was studied in cooperation with Dr. Pharo of Canada Centre for Inland Waters by providing lead-210 dating and interpretation at Ocean Chemistry Division. The effects of dumping mine tailings from a lead-zinc mine were assessed in relation to the natural sedimentary processes occurring. Against a background value of about $2-4 \mu\text{g lead cm}^{-2} \text{ yr}^{-1}$, the lead flux has increased by an order of magnitude or more since 1905 due to mining.

Arctic Waters Chemistry

No field work was attempted in 1979. The major effort was devoted to working up the backlog of data and samples. Lead-210 dating of marine sediment in cores collected in Amundsen Gulf was obtained by a beta-counting technique. Nutrients and chemical oceanographic data from the Beaufort Sea were processed into report format.

Salinity and dissolved (reactive) silicate were used to study the origin of surface water for the southern Beaufort Sea. By this method it was possible to estimate the relative contribution of sea-ice melt, Mackenzie River water and high salinity, but nutrient depleted, water off the Tuktoyaktuk Peninsula.



PERCENTILE TYPE I WATER

Contours of the percentile contribution of water with the composition of 32‰ salinity, 0 µg. At. L-1 of dissolved silicate

Weathership Program

Open-ocean effort was devoted to a continuing study of the long-term trends of chemical parameters at Ocean Weather Station P (50°N 145°W). In 1979, part of the effort was diverted towards establishing a replacement program in anticipation of the phase-out of the weatherships in 1981. Neuston-net tows were made between Victoria and Station P to collect tarballs and other surface pollutants. Weekly samples of atmospheric CO₂, surface alkalinity, total CO₂ and surface radiocarbon were taken together with some continuous shipboard infrared measurements of marine air CO₂ and pCO₂ on the CCGS *Quadra*. Samples of nutrients were taken to provide information about long-term fluctuations and their relationship to circulation and the marine food chain. Particulate detrital organic carbon and chlorophyll *a* were also collected on the *Quadra*. Seasonal flux of particulate carbon down to intermediate waters of 1,000 m was observable in the summer, confirming an earlier study by the late Dr. John Strickland and Dr. Parsons, although the carbon flux appeared to be smaller by the present technique.

OCEAN ECOLOGY LABORATORY

R.O. Brinkhurst - Head of Division

M.J. Austin
K. Denman
*R.H. Herlinveaux

D. Mackas
S. Hill

*Joined during 1979

The major 1979 field effort of the Ocean Ecology section focussed upon an intensive study of the biological oceanography of the continental shelf region off southwest Vancouver Island. Our objectives in this program have been twofold. First, we are attempting to identify major features in the spatial and temporal patterns of plankton abundance (important because planktonic productivity forms the base of the food chain leading to pelagic and demersal fish stocks). Second, we hope to learn the links between the physical and biological systems and, in particular, to know which physical processes determine the location, timing, and intensity of plankton blooms in this region.

Sophisticated sampling technologies are essential to our plans for rapid and detailed survey of the continental shelf region. We have developed two unique automated systems in response to this need. One is a computer-interfaced vertical profiler which contains sensors measuring chlorophyll fluorescence, temperature, salinity, light transmittance, and depth. Continuous information from these sensors is used to select water bottle samples at up to ten discrete depths per sampling site. The water samples are subsequently analyzed for dissolved nutrients (essential for phytoplankton growth), dissolved oxygen (both a measure of previous biological activity and

a tracer of water movements), carbon fixation rate (a measure of present phytoplankton growth) and salinity (a check on the operation of the continuous sensors). The second data collection system is supplied with sample water from the ship's plumbing and measures phytoplankton and zooplankton concentrations while the ship is underway. Graphical display of the data is available immediately, and allows the construction of maps of near-surface plankton concentration over relatively large areas. An example of one of these maps appeared in the previous annual report. These maps are used to help select the optimum locations for detailed sampling of vertical distributions and processes by the profiler described above.

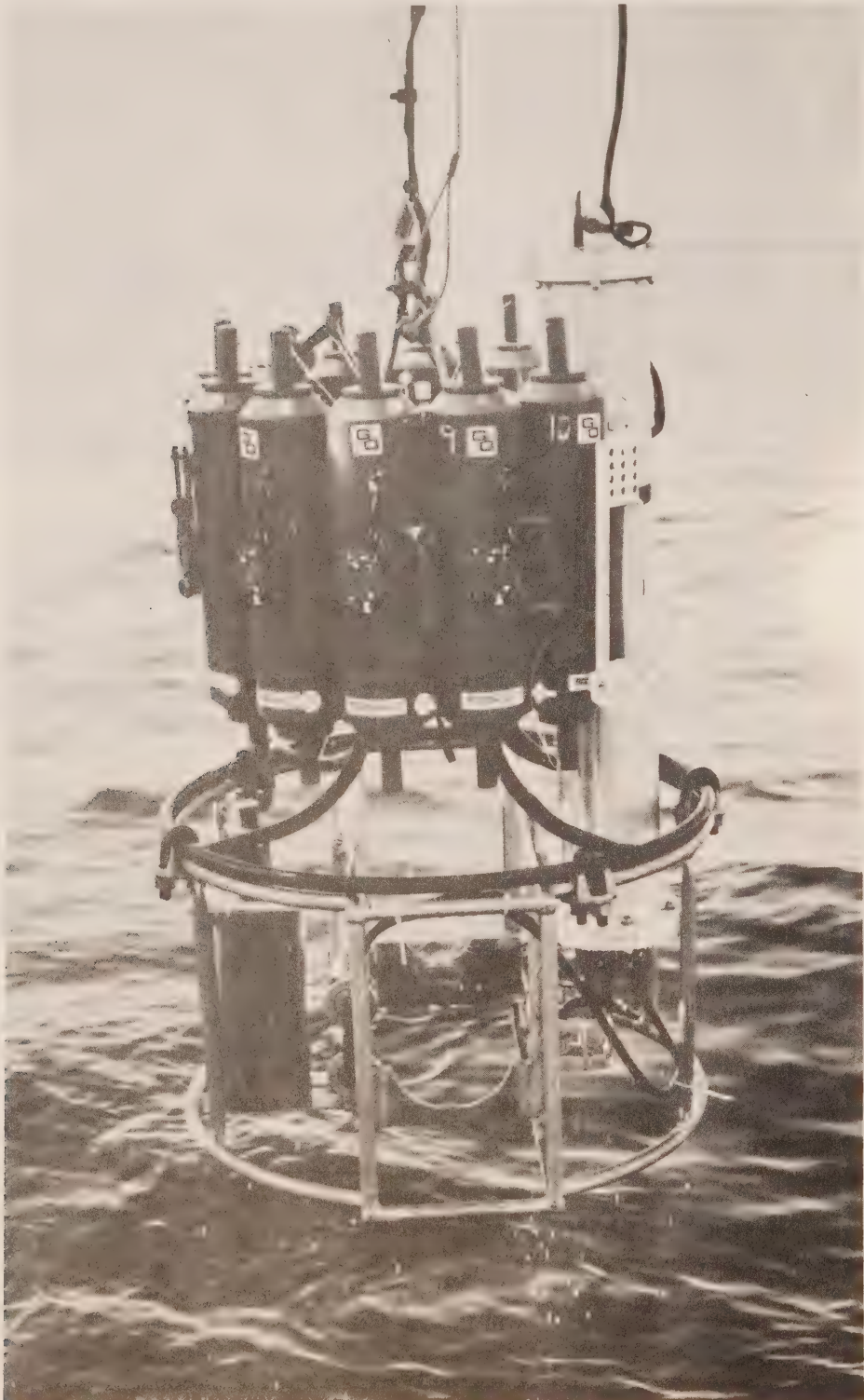
Although we have completed only the first year of this project and are currently analyzing data from the initial cruises, we have already identified two important features of the southern continental shelf ecosystem. We find that, unlike most places in the ocean, the near-shore portions of the shelf have high nutrient and phytoplankton concentrations throughout the summer months, probably resulting largely from the flow of nutrient-rich (due to tidal mixing and estuarine entrainment) surface water out of Juan de Fuca Strait and along the coast of Vancouver Island. We have also discovered a highly localized band of nutrient and plankton enrichment running along the outer margin of La Perouse Bank.

Interpretation and planning of the detailed research cruises was aided significantly by supplementary data collected from commercial ships of opportunity, under a contract issued to Seakem Oceanography Ltd. and administered scientifically by the Ecology section. In addition, for the detailed interpretation of our results, we will rely heavily on the distributions of surface currents as observed in the related programs carried out by the Coastal Zone Oceanography, Offshore Oceanography, and Tides and Currents Sections of the Institute.

At workshops in the spring, the various efforts to obtain bio-oceanographic data from ships of opportunity and from aircraft will be examined in relation to the weather ship and lighthouse data series in an attempt to draw together a proposal for a future time-series of observations off the west coast of the island and elsewhere if feasible. The work will be done largely under contract.

Benthic studies have continued to concentrate on the demand for identification of marine oligochaetes and the provision of manuals for government and industry scientists on a world-wide basis. Surveys of estuaries in Europe and the U.S.A., and of oil-lease tracts of seabed have resulted in large benthic surveys being undertaken in many non-Canadian institutions, producing a large increase of knowledge and species to be described by the two active taxonomic centers here and in Sweden. The first international gathering of "sludge worm" biologists was held at the Institute with support by NESRC, University of Victoria and Fisheries and Oceans. The resulting volume will appear early in 1980. Three scientists from the USSR and one from Poland joined European and American authorities, and the second and third sessions are planned in Europe. Critical material was obtained as a result of a visit to Hamburg. Two major contract studies are in progress; one on the effect of worms on sediment cycling involving heavy metals and bacteria, one on the short and long term toxicity of various pollutants to resistant and sensitive species in the laboratory.

Ocean dumping permits were processed as usual, and the Ocean Dumping Research fund was administered, again with a workshop to analyse results and plan future work as well as to prepare a brief annual report.



Ocean Ecology vertical profiler

SHIP DIVISION

E.N. Geldart - Regional Marine Superintendent

*N. St. C. Norton - Assistant Marine Superintendent (Deck)

R.W. Parkinson - Assistant Marine Superintendent (Eng.)

D.J. Redman - Design Draftsman

D.A. Doyle - Secretary

*Left in 1979

The Pacific Region Ship Division provided ship, submersible, launch and depot support for the 1979 hydrographic and scientific programs and for various federal departments and universities.

CSS *Parizeau* (64.3 m overall, 1929 tonnes)

Master: A.G. Chamberlain

Chief Engineer: P. Olcen

CSS *Parizeau* was employed in support of scientific and hydrographic programs involving Hydrography, Tides and Currents, Ocean Chemistry, Ocean Ecology, Offshore Oceanography; Loran C calibration; Pacific Geoscience Centre Geology; Department of National Defence, Ocean Acoustics; University of British Columbia, Oceanography.

CSS *Wm. J. Stewart* (65 m, 1920 tonnes)

CSS *Wm. J. Stewart* was sold to local interests and it is thought this ship will be used in a non-operational way in the tourist industry.

CSS *Vector* (39.6 m, 505 tonnes)

Master: K. Sjöholm

Chief Engineer: R. Gibson

CSS *Vector* carried out programs in support of Coastal Zone Oceanography, Ocean Chemistry, Offshore Oceanography, Ocean Ecology; Pacific Environmental Institute, Biology; Environmental Protection Service; University of British Columbia, Oceanography; Simon Fraser University, Oceanography.

CSS *Richardson* (19.8 m, 78 tonnes)

Master: M.G. Wheeler

Chief Engineer: I.N. Henderson

CSS *Richardson* was used mainly in Queen Charlotte Islands hydrographic survey and in search and rescue operations.

MV *Radium Express* (22.2 m, 100 tonnes) on charter

Master: I. Wiebe

Chief Engineer: N. Boudreau

Mackenzie River and Mackenzie Bay hydrographic surveys continued with the MV *Radium Express*. 1979 marks the last year of this series of survey seasons on the Mackenzie River system.

MV *Pandora II* (58.2 m, 1220 tonnes) on charter

Master: R.A. Jones

Chief Engineer: J. Newton

MV *Pandora II* carried out programs in support of Simon Fraser University; Environmental Protection Service; Ocean Chemistry and Offshore Oceanography; in conjunction with *Pisces IV*, the vessel supported programs for Coastal Zone Oceanography and Tides and Currents and supported *Pisces IV* during trials for the modified 2000 metre depth capability.

PISCES IV (6.1 m, 12 tonnes)

Chief Pilot: *I. Sanderson
F. Chambers

*Left in 1979

PISCES IV, our deep-dive submersible, received an extensive modification and was test-dived to 2000 metres. The development of a new tracking system is currently awaited which will enable this craft to perform at the maximum depth level of 2000 metres. *PISCES IV* was flown by Hercules to the Atlantic coast to undergo an interface exercise with the Canadian Forces vessel *Cormorant* and travelled to Lancaster Sound on the Canadian Forces vessel.

Barge *Pender*

Construction on the barge *Pender* was finally completed and the craft fitted out as a submersible tender vessel. The combination *Pender/Pisces IV* was towed to Jervis Inlet by the Canadian Forces Auxiliary Vessel *St. Anthony* on a successful shake-down cruise in December and work was performed for Pacific Geoscience Centre Geology on the return voyage to Patricia Bay.

Launches

CSS *Parizeau* hosted a four launch survey party in the Laredo Sound area and launches were used in Tuktoyaktuk and Summers Harbour in the Western Arctic.

Depot

The depot workshops continue to provide support to Institute activities in addition to the provision of repairs to ships and launches.

MANAGEMENT SERVICES DIVISION

N.A. Todd - Chief Management Services

Batchelor, R.J.	
Coldwell, J.H.	-Stores
*Cotter, M.L.	
Craton, M.I.K.	
*Crouch, R.W.	-Purchasing
Curtis, J.N.	
Deane, G.J.	
Deput, R.M.	
Doyle, D.A.	-Secretary, Regional Marine Superintendent
Drysdale, A.E.	
Firth, C.	
Hall, E.J.	
Hamilton, K.R.	-Personnel
*Harbar, M.S.	
Jones, K.M.G.	-Secretary, Chief, Management Services
Knapp, B.M.	-Pay and Benefits
Lapp, B.I.	
Lohrmann, B.A.	-Administrative Services
Mathias, A.L.	-Secretary, Ocean Chemistry Division
McKenzie, S.D.	-Secretary, Regional Hydrographer
Mikkelsen, M.L.	
Olauson, E.J.	
Parsons, J.E.	-Finance
Peirson, E.	-Secretary, Ocean Physics Division
Reinstein, H.G.	-Facilities Operation and Maintenance
Sabourin, J.T.	
*Smith, R.M.	
Stevens, I.B.	
*Thomas, C.D.	-Central Registry
Thomson, L.S.C.	-Library
van Dusen, T.S.	-Secretary, Director-General
Wonnacott, D.C.	-Secretary, Ocean Physics Division

*Left during 1979

Commissionaires

Sgt. D.W. Price
Sgt. W.L. Caldwell
Comm. J. Gessner
Comm. L. Brown

Comm. G. Glass
Comm. S. McMillen
Comm. H. Moffat
Comm. A. Samouelle

Comm. L. Trerice
Comm. J. Quinton
Comm. T. Osborne

Institute of Ocean Sciences

This will be the last report on construction of our new facilities. Most of the major contracts were completed in 1978, and in 1979 we were mainly occupied with clearing up deficiencies and having some troubles corrected during the warranty period. At the time of writing there is only one contract (for an environmental cold room) which has not been completed.

For the majority of the staff the construction process had its finale when, on 28 February, the Governor-General officially opened the Institute. Our former Minister, Mr. Le Blanc and our Deputy Minister, Mr. Tansley, were also present along with representatives from the provincial and municipal governments, and the Capital Regional District. Dr. Stewart hosted the guests, cutting short a trip to Europe to be present for the occasion.

Construction activity at Patricia Bay is, however, about to start again. The original planning for the Institute of Ocean Sciences included another objective to have the private sector in close proximity. During the past year negotiations have been underway with the British Columbia Development Corporation to establish a Marine Technology Centre on part of the site. Agreement has been reached and the Development Corporation anticipates it will be calling tenders for construction early in 1980 with anticipated completion of a first building by mid summer.



Dr. R. W. Stewart and guests at an IOS luncheon following the official opening.

Administration

Perhaps the most significant development in Administration in 1979 was establishment of a regional personnel office in the Institute. Ms. Kathleen Hamilton was appointed Regional Personnel Manager, reporting to the Director-General.

There was a larger than usual turn-over in staff during the year which, coupled with restrictions on hiring, placed additional burdens on the remaining staff. Nevertheless, the routine work in finance, materiel management and records management was completed. The continued development of our materiel inventory system is also worth mention.

The number of people visiting the Institute continued to increase. It is particularly rewarding to note that many of the local schools view a visit to the Institute an important item in their curricula. Many written and verbal compliments to our commissionaires and our scientific and technical staff have been received. A French version of the audio-visual show, with which we start the tours, is now available.

Local press coverage of Institute activities was extensive and generally of a high standard.

Progress has been made in our energy conservation measures. Various changes have been made to procedures and in some hardware in order to reduce energy consumption. A study on the possibility of using solar energy for powering some of the systems has been initiated.

LIBRARY

L.S.C. Thomson - Librarian

C. Firth - Library Clerk

The highlight of 1979 for the Library was the development of a program to put the Library's catalog on the computer. After four years of intermittent discussion and some abortive attempts, the program has metamorphosed into a very usable one. We look forward to spending a considerable proportion of our time in 1980 entering the data and producing a printed catalog.

The Library's budget was decreased and the combined effects of price rises and inflation have resulted in cuts in the journal subscriptions, as well as curtailment in book purchases. We have, however, received increased patronage from outside borrowers, who are very willing to pay for services.

TASK FORCE, COMMITTEE AND SIMILAR ACTIVITIES

DIRECTOR-GENERAL'S OFFICE

Mann, C.R.

Scientific Advisory Board, Intergovernmental Oceanographic Commission. (Chairman)

Advisory Panel on Oceans, Strategic Grants Committee, National Science and Engineering Council. (Chairman)

Sea Use Council (Canada-U.S.). (Vice-Chairman)

International Committee for the Exploration of the Sea. (Canadian Delegate)

Science Council of B.C., Research Evaluation Sub-Committee Ocean and Marine Resources Group.

Atlantic Research Directors Committee.

Canadian Oceanographic Delegation to China.

World Climate Conference. (IOC Representative)

Cornford, A.B.

Working Committee for Global Investigations of Pollution in the Marine Environment (GIPME). (Canadian Delegate)

IGOSS (MAPMOPP/MARPOLMON). (Canadian Delegate)

Institute Management Committee.

HYDROGRAPHIC DIVISION

Ages, A.B.

Environmental Emergency Working Group, Victoria Zone.

Technical Committee (DOE), Annacis Island Sewage Treatment.

Bolton, M.

Hydrographic Committee CIS.

National Hydrographic Survey Officers' Appraisal Board.

National Hydrographic Training Committee.

New Research/Survey Vessel Users Design Committee. (Chairman)

Pacific Sub-Committee on Oceanography of CCO. (Member)

Research Ship Scheduling Committee.

Joint DOE/DEMR Guiding Committee of Offshore Surveys.
 International Hydrographic Technical Conference (1979). (Chairman)
 Survey Engineering Advisory Committee, University of Calgary.
 FIG Commission IV. (Canadian Delegate)
 Management Committee IOS.
 Library Committee IOS. (Chairman)

Curran, T.A.

Electronics Technology Program Advisory Committee, Camosun College.

Galloway, J.L.

Steering Committee for the Establishment of International Shipboard
 Data Acquisition Standards.

Huggett, W.S.

New Research/Survey Vessel Users Design Committee.
 Environmental Emergency Working Group, Victoria Zone.
 Regional Hydrographic Survey Officers' Appraisal Board.

Larkin, J.E.

Canadian Institute of Surveying, Victoria Branch. (Secretary)

O'Connor, A.D.

Canadian Institute of Surveying, Victoria Branch. (Past Chairman)
 Survey Technology Advisory Committee, BCIT.
 Regional Hydrographic Survey Officers' Appraisal Board.

Rapatz, W.J.

B.C. Civil Defense Tsunami Committee.
 Ocean Dumping Act. (Inspector)

Richardson, G.E.

Regional Hydrographic Survey Officers' Appraisal Board.

Sandilands, R.W.

Hydrographic Technical Committee, Canadian Institute of Surveying.

The Canadian Surveyor. (Associate Editor (hydrography))
 Lighthouse - Canadian Hydrographers Association. (Assistant Editor)
 Survey Technology Advisory Committee - Camosun College.
 Board of Trustees, Maritime Museum of B.C. (Past Chairman)
 International Hydrographic Technical Conference Committee (1979).
 Canadian Institute of Surveying, Victoria Branch. (Vice-Chairman)
 Canadian Hydrographers Association, Pacific Region. (Executive member)
 Regional Hydrographic Survey Officers' Appraisal Board. (Chairman)
 Library Committee IOS.

Smith, A.

Sub-committee of CPCGN for Undersea Features.
 (Canadian Permanent Committee Geographical Names)

Stephenson, F.E.

IOS Safety Committee.

Watt, J.V.

Electronics Technology Program Advisory Committee, Camosun College.

Wills, R.

Regional Hydrographic Survey Officers' Appraisal Board - Chairman
 Regional Committee on Interagency Routing of Navigational Information
 Survey Technology Advisory Committee, BCIT
 Regional Board, Pacific Region, Estuary Working Group

Wigen, S.O.

International Co-ordination Group for the Tsunami Warning System in the
 Pacific - National Representative
 Canadian Working Group on the Use of Satellites in the Tsunami Warning
 System - Chairman
 Joint Federal/Provincial Tsunami Working Group - Chairman

OCEAN CHEMISTRY DIVISION

Cretney, W.J.

Laboratory Safety Committee, Ocean Chemistry. (Chairman)

Institute Safety Committee.

Institute Cafeteria Committee.

Chemical Institute of Canada, Vancouver Island Section. (Secretary)

Organizing Committee - CIC Symposium on "Marine Chemistry into the Eighties".

Macdonald, R.W.

Ocean Dumping Technical Sub-Committee, Pacific Region.

Arctic Petroleum Operators Association/Government Steering Committee on Offshore Drilling Fluid Disposal.

Joint Industry/Government Steering Committee on Problems on Arctic Hydrocarbon Development: Working Group on Ice Scours.

Organizing Committee - CIC Symposium on "Marine Chemistry into the Eighties".

Organizing Committee - NATO Fjord Workshop Symposium.

Thompson, J.A.J.

Institute Safety Committee.

Laboratory Safety Committee - Ocean Chemistry.

Pacific Nuclear Activation Research Association. (Secretary)

Chemical Institute of Canada, Vancouver Island Section. (Vice-Chairman)

Organizing Committee - CIC Symposium on "Marine Chemistry into the Eighties". (Chairman)

Wong, C.S.

Environmental Contaminant Act Advisory Committee, Pacific Region.

NRC Associate Committee on Marine Analytical Standards, Atlantic Regional Laboratory.

CO₂ Standardization Committee - GEOSECS.

Organizing Committee, NATO Advanced Research Institute on "Accurate Measurement of Trace Metals in Sea Water". (Chairman)

Local Organizer, Symposium on Controlled Experiments, August, 1980.

Institute Management Committee.

OCEAN ECOLOGY LABORATORY

Brinkhurst, R.O.

University of Victoria. (Honorary Professor)

Royal Ontario Museum. (Research Associate)

North American Benthological Society. (President-Elect)
 American Society Limnology and Oceanography.
 Regional Ocean Dumping Advisory Committee. (OAS Representative)
 Science Subvention Assessment. (OAS Representative)
 Standards Council of Canada - ISO/TC/147/ScS Member.
 First International Aquatic Oligochaete Biology Symposium. (Chairman
 and Proceedings Editor)
 Rawson Foundation. (Fellow)
 European Marine Biological Symposium (Helgoland). (Session Chairman)
 University of Hamburg, Zoological Institute and Museum. (Visiting
 Investigator)
 University of Victoria. (Graduate Student Committees (3))
 Institute Management Committee.

Denman, K.L.

Canadian Marine Sciences Delegation, China.
 Canadian Meteorological and Oceanographic Society. (Chairman,
 Citations Committee)
 American Society Limnology and Oceanography. (Member, Nominations
 Committee)

Herlinveaux, R.H.

Regional Ocean Dumping Advisory Committee (Arctic).
 Oil Spill Emergency Team. (OAS Representative)
 Arctic Waters Advisory Committee. (OAS (Alt.) Representative)

Mackas, D.

University of Victoria. (Adjunct Assistant Professor)

OCEAN PHYSICS DIVISION

Bell, W.H.

RODAC Technical Sub-Committee.

Farmer, D.M.

Babine Lake Steering Committee.
 AGU Estuarine Coastal Oceanography Committee.

Garrett, J.F.

Committee of Participants in the Southern Hemisphere Drifting Buoy
 System for the FGGE. (Chairman)

Giovando, L.F.

Joint Working Committee Lower Fraser River Environmental Monitoring.
 B.C. Coastal Zone Resource Sub-Committee.
 Roberts Bank Environmental Sub-Committee.

Gower, J.F.R.

Canadian Advisory Committee on Remote Sensing, Working Group on
 Oceanography. (Chairman)
 NAIA Seasat Synthetic Aperture Radar Experiment Team.
 IUCRM Inter Union Commission on Radio Meteorology.
 SCOR representative to COSPAR.

Henry, R.F.

University of Victoria Co-operative Education Advisory Council.
 (IOS Representative (since Oct.1979))

Lake, R.A.

Arctic Marine Oilspill Program (AMOP) - Management Committee.
 Arctic Water Advisory Committee (AWAC). (Alternate Representative)

Lewis, E.L.

UNESCO/SCOR/IAPSO/ICES Joint Panel of Experts on Oceanographic
 Tables and Standards (SCOR W.G. 10).
 SCOR/IAPSO Working Group 51 - Evaluation of CTD Data.
 SCOR Working Group 58 - Arctic Ocean Heat Budget.
 Canadian Committee on Oceanography Panel on Ice - Arctic Oceano-
 graphy Sub-Committee.
 Marine Science Communications - Editorial Advisory Board.
 Canadian National Committee for SCOR.
 Arctic Water Advisory Committee (AWAC).

Murty, T.S.

IUGG Tsunami Committee. (Canadian representative and Vice-Chairman)
 Canadian Meteorological and Oceanographic Society (CMOS). (Recording
 Secretary (until June 1979))
 Journal of Marine Geodesy. (Associate Editor)
 University of Quebec at Rimouski. (Honorary Director of Research)

U.S. Marine Technology Society Panel. (Tsunami expert)

Canadian Working Group on the Use of Satellites in the Tsunami Warning System.

DFO Advisory Board on Scientific Information and Publications. (IOS representative)

Smiley, B.D.

Fate and Effects Working Group of Advisory Group on Research and Development and Member (EPS-AGRAD) Petrocan Environmental Advisory Committee.

Tabata, S.

Ocean Climate Panel of Working Group 48 of the Scientific Committee on Oceanic Research (SCOR).

Integrated Global Ocean Systems (IGOSS). Sub Group on Scientific Matters.

Organizing Committee of the 13th Canadian Meteorological and Oceanographic Congress (disbanded November 1979).

Thomson, R.E.

RSCC Committee on Burrard Inlet Floating Drydock.

Atmosphere-Ocean. (Associate Editor)

Canadian Meteorological and Oceanographic Society, Vancouver Island Centre. (Treasurer)

B.C.-Yukon Inuit Regional Committee of the Professional Institute. (Victoria Representative)

COMPUTING SERVICES

Teng, K.

Organizing Committee for CIPS '80 National Computer Conference. (Co-Secretary)

Johns, R.E.

Organizing Committee for CIPS '80 National Computer Conference. (Treasurer)

Canadian Information Processing Society, Victoria Section. (Treasurer)

SHIP DIVISION

Geldart, E.N.

Pacific Regional Resource/Survey Vessel Committee. (Secretary)

CONTRACTS AWARDED DURING 1979/80

Oceanographic Data Collection on the Fraser River Estuary J. Bruce, Sidney, B.C.	6,000
Preparation for library catalogue of scientific reports concerning Tsunami tidal waves A. Kriz, Victoria, B.C.	2,744
Feasibility examination of alternative electronic operating systems for a turbulent velocity measurement probe Cardec Engineering Ltd., Victoria, B.C.	3,700
Development of a public information program on the scientific programs within the Institute of Ocean Sciences Taiga Management Ltd., Victoria, B.C.	8,900
Numerical modelling studies of the estuarine circulation in the Strait of Georgia System - Part I University of British Columbia, Vancouver, B.C.	10,000
Processing of physical oceanographic data as returned by oceanographic observers from the weathership QUADRA and VANCOUVER Interact Computing Services, Victoria, B.C.	3,809
Study to determine the tidal residual circulation in the Juan de Fuca and Georgia Strait system Beak Consultants, Vancouver, B.C.	151,741
Analysis of offshore oceanographic data from Line P experiment B. Choo, Victoria, B.C.	3,500
Design and write a data storage and processing computer program for the digitization of tsunami traces appearing on tidal marigrams B. Waring, Victoria, B.C.	1,500
Development of computer programs for ocean mixing Apocalypse Enterprises Ltd., Victoria, B.C.	19,436
Development of computer programs for remote sensing Apocalypse Enterprises Ltd., Victoria, B.C.	9,968
Continuing support for the West Coast Ocean Dumping Program Dobrocky Seatech Ltd.	9,000
Development of computer programs for fluid problems in fjords and coastal waters CPRO Computing Enterprises Inc., Victoria, B.C.	22,500

Development of computer programs for Tides & Currents CPRO Computing Enterprises Inc., Victoria, B.C.	24,957
Data preparation and drafting of diagrams for scientific publications C. Wallace, Sidney, B.C.	3,037
Study and analysis of plankton samples from B.C. coastal waters G. Gardner, Brentwood Bay, B.C.	5,450
Identification of marine oligochaeta obtained from the Strait of Juan de Fuca H.R. Baker, Victoria, B.C.	2,000
Preparation of an index of data collected during the Kitimat oceanographic study Dobrocky Seatech Ltd., Victoria, B.C.	4,441
Carry out simultaneous deployment of three controlled ecosystem enclosures J&J Divers, Victoria, B.C.	975
Analysis of dissolved nutrients in seawater Seakem Oceanography Ltd., Sidney, B.C.	19,575
Study of remote sensing of open ocean chlorophyll and temperature Seakem Oceanography Ltd., Sidney, B.C.	56,917
Assessment of mussel health and surface sediment concentrations of polycyclic hydrocarbons in Alberni Inlet Seakem Oceanography Ltd., Sidney, B.C.	15,953
Provision of oceanographic support to the Institute of Ocean Sciences Dobrocky Seatech Ltd., Victoria, B.C.	20,000
Provision of support to IOS to carry out oceanographic programs Bastion City Charters Ltd., Nanaimo, B.C.	10,000
Analysis of seawater and air samples from weatherships Seakem Oceanography Ltd., Sidney, B.C.	40,000
Continuing development of alternative electronic operating systems for a turbulent velocity measurement probe Cardec Engineering, Victoria, B.C.	5,500
Review of oceanographic data relating to ocean dumping in the Prince Rupert area EVS Consultants, Vancouver, B.C.	14,212

Analysis of data relating to dumpsite colonization and temporal changes in benthic communities in Alberni Inlet EVS Consultants Ltd., Vancouver, B.C.	6,974
Dissolved oxygen study of deep waters in the inner basin of Alberni Inlet Dobrocky Seatech Ltd., Victoria, B.C.	114,726
Analysis of B.C. coastal water data from the Dept. of Fisheries and Oceans colour spectrometer Seakem Oceanography Ltd., Victoria, B.C.	5,587
Analysis of oceanographic data collected by the weatherships and selected shore stations D. Ramsden, Victoria, B.C.	6,825
Documentation and data quality control of First GARP Global Experiment T. Garrett, Victoria, B.C.	8,684
Compilation of Pacific Region data for data acquisition and management plan report P.W. Nasmyth, Victoria, B.C.	380
Development, construction and testing of a scientific research system for in situ chemical studies Case Existological Labs Ltd., Victoria, B.C.	272,698
Development and logistics planning and coordination for GARP First Global Experiment Beak Consultants, Vancouver, B.C.	113,819
Feasibility study using ships of opportunity to collect physical and biological oceanographic data Seakem Oceanography Ltd., Sidney, B.C.	22,373
Development of microprocessor based acoustic navigation system for surveying from a small submarine Mesotech Systems Ltd., Vancouver, B.C.	26,415
Modification of the Department of Fisheries and Oceans submersible PISCES IV International Hydrodynamics, North Vancouver, B.C.	1,500
Collection of zooplankton samples aboard the CSS <i>Vector</i> H. Sefton, Victoria, B.C.	1,556
Laboratory study of behaviour of oil and gas particles in salt water relating to deep oil well blowouts University of Calgary	24,043

Collection and supply of hydrographic field data for corrections and updating navigational charts and sailing directions Coast Pilot Ltd., Sidney, B.C.	34,000
Oceanographic observations aboard CCGS QUADRA G. Jewsbury, Victoria, B.C.	6,014
Preparation of materials for Beaufort Sea technical and scientific overview reports Hoot Productions, Victoria, B.C.	13,050
Oceanic water properties sampling and measurement program aboard CCGS QUADRA Seakem Oceanography Ltd., Sidney, B.C.	8,895
Study on the occurrence and nature of tin and its organic derivative in sewage wastes, industrial effluents, fresh and saline waters of southwest B.C. University of B.C., Vancouver, B.C.	21,346
Biological and oceanographic research support to IOS University of Victoria, Victoria, B.C.	2,000
Analysis of dissolved nutrients in seawater Seakem Oceanography Ltd., Sidney, B.C.	3,930
Historical study of tsunami data extraction M. Lane, Victoria, B.C.	3,000
Lethal and sublethal tolerances of aquatic oligochaetes with reference to their use as biological indicators of pollution EVS Consultants, Vancouver, B.C.	140,000
Preparation of a report on Ocean Weather Station P particulate organic carbon data K. Iseki, Sidney, B.C.	2,500
Analysis of seawater and air samples from weathership Seakem Oceanography Ltd., Sidney, B.C.	15,000
Study of pingo-like features detected in the Beaufort Sea Coast Pilot Ltd., Sidney, B.C.	6,982
Statistical analyses of pingo-like features in the Beaufort Sea Barrodale Computing Services Ltd., Victoria, B.C.	3,700
Development of computer programs for tides and currents CPRO Computing Enterprises Inc., Victoria, B.C. (amendment)	11,535

Study on the acoustic target strength of pingo-like features found in the Beaufort Sea Geomarine Associates Ltd., Halifax, N.S.	4,000
Study on behaviour pathways, residence time and toxicity of Pentachlorophenol in the marine environment Dobrocky Seatech Ltd., Victoria, B.C.	29,546
Study on applying side-tow techniques for hydrographic surveys B.C. Research, Vancouver, B.C.	10,000
Study of digital terrain modelling to hydrographic survey charting activities Barrodale Computing Services Ltd., Victoria, B.C.	3,940
Pingo correlation and prediction study J. Shearer, Ottawa, Ontario	12,371
Development of hydrographic resource allocation package Coast Projects Ltd., Victoria, B.C.	9,920
Amendment to feasibility study using ships of opportunity to collect physical and biological oceanographic data Seakem Oceanography Ltd., Sidney, B.C.	22,373
Amendment to the development of a microprocessor based, precision acoustic navigation system for surveying from a small submersible Mesotech Systems Ltd., North Vancouver, B.C.	26,415
Oceanographic observations aboard CCGS QUADRA G. Jewsbury, Victoria, B.C.	6,014
Oceanic water properties sampling and measurement program aboard CCGS QUADRA (amended) Seakem Oceanography Ltd., Sidney, B.C.	88,950
Preparation of a manual containing detailed descriptions of the programs used to process STD and hydro data collected by weatherships Interact Computing Services Ltd., Victoria, B.C.	6,000
Processing of oceanographic data from Alberni Inlet Interact Computing Services Ltd., Victoria, B.C.	4,980
Feasibility study for a wide swath sonar system Mesotech Systems Ltd., North Vancouver, B.C.	21,153
Study on the migration of mercury from sediments Chemex Labs Ltd.	29,895

Evaluation of sonar equipment and techniques for applications in the Beaufort Sea Huntec (70') Ltd., Scarborough, Ont.	34,000
Study on applying side-tow techniques to hydrographic surveys B.C. Research, Vancouver, B.C.	10,000
Pingo correlation and prediction study Geomarine Assn., St.Johns, Nfld., and S. Shearer, Ottawa, Ont.	4,000
Analysis of calibration samples for ocean ecology profiler A. Sinclair	3,925
Drafting and photographic services Techni-Graphics	1,900

PUBLICATIONS

Institute of Ocean Sciences, Patricia Bay, 1979 Annual Report

PACIFIC MARINE SCIENCE REPORTS

PMSR 79-1

Miyake, M.

Oceanographic observations at Ocean Station P during mixed layer experiment August 1, 1978. Volume 84-B.

PMSR 79-2

Miyake, M.

Oceanographic observations at stations along the triangular grids during the mixed layer experiment August 1, 1978. Volume 84-C.

PMSR 79-3

Mortimer, A.R.

A Loran-C calibration, the West Canadian chain cycle selection tests.

PMSR 79-4

Brinkhurst, R.O.

Distribution of aquatic oligochaeta in some habitats of lower British Columbia.

PMSR 79-5

Byers, S.C. and R.O.
Brinkhurst, Eds.

Report on ocean dumping R and D, Pacific Region, Fisheries and Environment Canada 1977-78.

PMSR 79-6

Oceanographic observations at Ocean Station P 16 June - 2 August 1978. Volume 92.

PMSR 79-7

Oceanographic observations at Ocean Station P 28 July - 13 September 1978. Volume 93.

PMSR 79-8

Oceanographic observations at Ocean Station P 8 September - 26 October 1978. Volume 94.

PMSR 79-9

Oceanographic observations at Ocean Station P 20 October - 6 December 1978. Volume 95.

PMSR 79-10

Oceanographic observations at Ocean Station P 1 December 1978 - 10 January 1979. Volume 96.

PMSR 79-11

Murty, T.S. and R.E.
Brown

The submarine slide of 27 April, 1975 in Kitimat Inlet and the water waves that accompanied it.

PMSR 79-12 (Pts. I & II)

Coastal Zone Oceanography
Section

Oceanographic observations in Knight Inlet,
B.C. Volume I: Salinity/temperature profile
Part I: 1977, Part II: 1978.

PMSR 79-13

Crean, P.B., M. Miyake and
W.S. Huggett

Data report of STD observations Volume 1:
Strait of Juan de Fuca 1973.

PMSR 79-14

Ages, A.

Salinity intrusion in the Fraser River:
Salinity, temperature and current observations,
1976, 1977.

PMSR 79-15

Foreman, M.G.G. and R.F.
Henry

Tidal analysis based on high and low water
observations.

PMSR 79-16

Herlinveaux, R.H.

Oceanographic observations in Robeson Channel,
N.W.T. 1971.

PMSR 79-17

Thompson, J.A.J., D.W.
Paton and M. Timmons

Copper and zinc in sediments of Georgia Strait,
B.C. in the vicinity of Texada Mine.

PMSR 79-18

Byers, S.C. and R.O.
Brinkhurst, Eds.

Report on ocean dumping R and D Pacific
Region Department of Fisheries and Oceans
1978-1979.

PMSR 79-19

Tabata, S. and P.M.
Kimber

Satellite observations of sea surface
temperature patterns off the Pacific coast
of Canada.

PMSR 79-20

Bell, W.H.

A three-dimensional subsurface mooring model.

PMSR 79-21 (Pts. I, II, III, IV)

Coastal Zone Oceanography
Section

Salinity/temperature profiles in Haro Strait,
B.C. Part I: April-July 1976, Part II:
September-October 1976, Part III: November-
December 1976, Part IV: January-April 1977.

CONTRACTOR REPORT SERIES

CRS 79-1

Lea, Brian N.,
Dobrocky Seatech Ltd.

Development, testing and deployment of moorings for use in areas of negligible horizontal magnetic field.

CRS 79-2

Conlan, K.E., S.C. Byers,
Ed., Dobrocky Seatech Ltd.

The biological effects of ocean dumping: a selected, annotated bibliography.

CRS 79-3

Beak Consultants Ltd.,
Vancouver, B.C.

An examination of the variability of upwelling on the west coast of Vancouver Island and its relationship to the flushing of Alberni Inlet.

OTHER PUBLICATIONS - 1979

- Ages, A.B. 1979. Oil spill modelling in British Columbia: In: Oil Spill Modelling, Proceedings of a Workshop. D. Mackay, ed. Toronto, University of Toronto, 1979. pp.143-149.
- Baker, H.R. and C. Erseus. 1979. Peosidrillus biprostatatus n.g.n. sp. a marine tubificid (oligochaeta) from the eastern United States. Proc. Biol. Soc. Wash. 92: 505-509.
- Bell, W.H. 1979. The influence of turbulence on drag. Ocean Engng. 6 329-340.
- Brinkhurst, R.O. 1979. A new species of Limnodrilus (Oligochaeta, Tubificidae) from Jamaica. Proc. Biol. Soc., Wash. 92: 42-44.
- Brinkhurst, R.O. 1979. On the types in the genus Peloscolex Leidy (Oligochaeta, Tubificidae). Proc. Biol. Soc. Wash. 92: 677-681.
- Brinkhurst, R.O. and M.J. Austin. 1979. Assimilation by Aquatic Oligochaeta. Int. Rev. Ges. Hydrobiol. 63: 245-250.
- Brinkhurst, R.O. and H.R. Baker. 1979. A review of the marine Tubificidae (Oligochaeta) of North America. Can. J. Zool. 57: 1553-1569.
- Brinkhurst, R.O. and W. Fulton. 1979. Some aquatic Oligochaeta from Tasmania. Rec. Queen Victoria Mus. 64 :1-8.
- Crawford, W.R. 1979. Pressure measurements on seamounts in the North Pacific. Proc. Symposium on Long Waves in the Ocean. Manuscript Report Series No.53, Marine Sciences Directorate, Ottawa.

- Crawford, W.R. and T.R. Osborn. 1979. Microstructure measurements in the Atlantic Equatorial Undercurrent during GATE. Deep-Sea Res., GATE supplement II to 26: 285-308.
- Crawford, W.R. and T.R. Osborn. 1979. Energetics of the Atlantic Equatorial Undercurrent. Deep-Sea Res., GATE supplement II to 26: 309-324.
- Cretney, W.J., W.D. Jamieson, M.D. Mackinnon and D.R. Green. 1979. A GC/MS study of the total fluorescence method for the analysis of polynuclear aromatic hydrocarbons in sea water. In: Proc. of the 27th Annual Conference on Mass Spectrometry and Allied Topics, American Society for Mass Spectrometry. (An extended abstract.)
- Cretney, W.J., E.J. Carpenter, B.F. Morris and R.K. Swanson. 1979. Litter. Proc. of a Workshop on Scientific Problems Relating to Ocean Pollution, Estes Park, Colorado, July 10-14, 1978: 51-68.
- Farmer, D.M. and H.E. Huppert. 1979. The oceanography of fjords. Nature 280: 273-274.
- Farmer, D.M. and J.D. Smith. 1979. Internal waves during GATE. Deep-Sea Res. 26A: 347-350.
- Freeland, H.J. 1979. Tidal analysis and the energetics of a deep stratified inlet. Proc. of the International Symp. on Long Waves in the Ocean, Ottawa.
- Foreman, M.G.G., L.M. Delves, I. Barrodale and R.F. Henry. 1979. On the use of the Proudman-Heaps Tidal Theorem. Geophysical J. of the Royl. Astr. Soc. (In press).
- Galloway, J.L. and R.C. Teichrob. 1979. SCRIBE data acquisition in a submersible. Proc. OCEANS '79, San Diego. pp. 772-776.
- Gargett, A.E. 1979. Turbulence measurements through a train of breaking internal waves in Knight Inlet, British Columbia. In Fjord Oceanography. Plenum Pr. (In press.)
- Gargett, A.E. and T.R. Osborn. 1979. Dissipation measurements from the Fine and Microstructure Experiment. Univ. of B.C. Inst. Oceanography Manuscript report no. 33. Vancouver.
- Gargett, A.E. and T.R. Osborn. 1979. Surface mixing layers in the Sargasso Sea. J. Phys. Oceanogr. 9: 6.
- Gonzales, F.E., R.C. Beal, W.E. Brown, J.F.R. Gower, D. Lichy, D.B. Ross, C.L. Reifenach and R.A. Shuchman. 1979. SEASAT synthetic aperture radar ocean wave detection capabilities. Science 204: 1418.
- Gower, J.F.R. 1979. The computation of ocean wave heights from GEOS-3 satellite radar altimeter data. Rem. Sensing Envir. 8: 97.

- Gower, J.F.R. and B.A. Hughes. 1979. Radar and ship observations of coastal sea surface roughness patterns in the Gulf of Georgia. Paper presented at 13th Symposium on Remote Sensing of Environment, Ann Arbor, Mich. Apr. 1979.
- Herman, A.W. and I.L. Denman. 1979. Intrusions and vertical mixing at the shelf/slope water front south of Nova Scotia. J. Fish. Res. Board Can. 36: 1445-1453.
- Holbrook, J., S. Frisch and A.B. Ages. 1979. Coastal forcing in the Strait of Juan de Fuca. AGU Fall 1979. (In press.)
- Lewis, E.L. 1979. Some possible effects of arctic industrial development on the marine environment. Proc. 5th Int. Conf. on Port & Ocean Engineering Under Arctic Conditions. Trondheim, Norway. pp. 369-392.
- Lewis, E.L. and N.P. Fofonoff. 1979. Notice to oceanographers, a practical salinity scale. Published in EOS; J. Phy. Oceanog.; Deep Sea Res.; Oceanologica (in Russian); J. Oc. Soc. Japan (in Japanese); etc.
- Mackas, D.L. and C.M. Boyd. 1979. Spectral analysis of zooplankton spatial heterogeneity. Science 204: 62-64.
- Milne, A.R. and R.H. Herlinveaux. 1979. Crude oil in cold water. Beaufort Sea Project Overview report. Victoria, Beaufort Sea Project.
- Mortimer, A.R. 1979. Comments on the Internav Loran-C Co-ordinate Converter Unit (CC-2). Lighthouse, edition no. 20: 22-24.
- Murty, T.S. 1979. A mathematical model for pre-boiling convection in a geyser vent. Amer. J. Sci. (In press).
- Murty, T.S. 1979. Contribution of physical oceanographic processes to sea level variation. Proc. of the International Conference on Marine Geodesy and Navigation, New Orleans, Oct. 10-12, 1979. Marine Technology Society. (In press).
- Murty, T.S. 1979. Submarine slide-generated water waves in Kitimat Inlet, British Columbia. J. of Geophys. Res. (In press).
- Murty, T.S., F.G. Barber, and J.D. Taylor. 1979. Role of advective terms in tidally generated residual circulation. Limn. and Oceanogr. (In press).
- Murty, T.S., M.I. El-Sabh, and J.M. Briand. 1979. Storm surge amplitudes in the St. Lawrence estuary. Lighthouse. (In press).
- Murty, T.S. and H.G. Loomis. 1979. A new tsunami magnitude scale. Newsletter of the International Tsunami Information Center, 12(2), 19pp.

- Murty, T.S. and M.C. Rasmussen. 1979. Plans for numerical modelling of circulation associated with sills in the Canadian Arctic Archipelago. Proc.of an Arctic Physical Oceanography Workshop, Oct.10-11, 1978, Inst.of Ocean Sciences, Patricia Bay, 18pp.
- Murty, T.S. and M.C. Rasmussen. 1979. Tidally-forced stratified flow over sills. Proc.of the Fjord Oceanographic Workshop, Victoria, B.C., June 4-8, 1979. Sponsored by N.A.T.O. as an Advanced Research Institute. (In press).
- Sandilands, R.W. 1979. I am become a name (West Coast toponymy). Canoma 5(1): 12-15.
- Sandilands, R.W. 1979. Whose name was writ in water: (A short history of the *Challenger* Expedition). Lighthouse, Edition no. 19: 1-6.
- Sandilands, R.W. 1979. Charlie Golf Foxtrot Quebec: (A history of the CSS *William J. Stewart*). Lighthouse, Edition no. 20: 1-3.
- Smiley, B.D. and A.R. Milne. 1979. LNG transport in Parry Channel: possible environmental hazards. Sidney, Institute of Ocean Sciences, Patricia Bay. 47p.
- Tabata, S. 1979. A need for improved quality of sea-surface temperature data from the world oceans. Intergovernmental Oceanographic Commission Workshop, Report no.17 - supplement: 481-492.
- Tabata, S. 1979. On the variability of water properties in the surface mixed layer at Station P. Limnol. and Oceanogr. 24(1): 158-163.
- Wigen, S.O. and M.G. Spaeth. 1979. Report on the use of satellites in the Tsunami Warning System. Tsunami Newsletter 12(2). International Tsunami Information Center.
- Wong, C.S., K.S. Johnson and R.M. Pytkowicz. 1979. Biological production and the exchange of oxygen and CO₂ across the sea surface in Stuart Channel, B.C. Limnol. and Oceanogr. 24(3), 474-482.
- Wong, C.S. 1979. Carbon input to the atmosphere from forest fires. Science, 204, 209-210.
- Woods, M.V. 1979. The Mini-Ranger Data Processor/Automated Positioning System - A useful tool for positioning sweeps. Lighthouse, no.19, 7-10.
- Yorath, C.J., B.D. Bornhold and R.E. Thomson. 1979. Oscillation megaripples on the northeast Pacific continental shelf. J.Mar.Geol.31: 45-58.

PERMANENT STAFF 1979

DIRECTOR GENERAL

*Stewart, R.W.; B.Sc., M.Sc. (Queen's), Ph.D. (Cantab), FRSC, FRS,
D.Sc. (McGill), LL.D. (Dalhousie).

Mann, C.R.; B.Sc., M.Sc. (N.Z.), Ph.D. (Brit. Col.), D.Eng. (N.S.Tech),
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ASSISTANT TO DIRECTOR GENERAL

Cornford, A.B.; B.Sc. (McMaster), Ph.D. (Brit. Col.) - Head, Program
Analysis & Liaison

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Drysdale, A.E.	*Smith, R.M.
Firth, C.	Stevens, I.B.; CIMA (McMaster)
Hall, E.J.	*Thomas, C.D.
Hamilton, K.R.; B.A. (Brit. Col.)	Thomson, L.S.C.; B.A. (Saskatchewan), B.L.S. (Brit. Col.)
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*Jones, K.M.G.	Wonnacott, D.C.
Knapp, B.M.	

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Sgt. W.L. Caldwell	Comm. S. McMillen	Comm. J. Quinton
Comm. J. Gessner	Comm. H. Moffat	Comm. T. Osborne
Comm. L. Brown	Comm. A. Samouelle	

*Left during 1979

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 (Brit.Col.), P. Eng.
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 Huggett, W.S.; Master, (FG)
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 *Parker, R.N.S.
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 Taylor, W.R.; Dip. RCC
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 Vosburgh, J.A.; Dip. BCIT
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* Left during 1979
 ** Joined during 1979
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M.Sc. (Brit.Col.)	Woollard, A.L.; B.Sc. (Victoria)

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Macdonald, R.W.; B.Sc., Ph.D. (Dalhousie)

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Ph.D. (Cantab)

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Kimber, P.M.

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(Dalhousie)

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Col.)

Topham, D.R.; D.L.C., D.C.A.E.,
Ph.D. (Loughborough)

Wallace, J.S.

*Left during 1979

SHIP DIVISION

Geldart, E.N. 1st Class Marine Engineer, Fellow Institute of Marine
Engineers; Regional Marine Superintendent

*Norton, N.St.C. Master F.G.; Assistant Marine Superintendent (Deck)

Parkinson, R.W. Engineer 1st Class Combined; Assistant Marine
Superintendent (Engineering), M.I.M.E.

*Henderson, J.D. Engineer 2nd Class Steam; Depot Supervisor

Smith, F.V.	Marine and Industrial Electrician; Depot Supervisor
Redman, D.J.	Design Draftsman; O.N.C.
P. Periera	Relief Chief Engineer, 1st Class Motor
J. Orr-Hood	Relief Senior Engineer; 3rd Class Motor
Bishop, S.O.	Master H.T.; Relief Chief Officer

CSS PARIZEAU

Chamberlain, A.G.	Master, F.G.; Master
Fisher, E.G.	Master, F.G.; 1st Officer
Newton, B.L.	Master, F.G.; 2nd Officer
*Christie, J.N.	Radio Certificate; W/O
Palmer S.	Supply Officer
Olcen, P.	Engineer 1st Class Motor, Chief Engineer
Gibson, R.B.	Engineer 3rd Class Motor, Senior Second Engineer
Flynn, J.	Engineer 3rd Class Motor, Second Engineer
Haines, T.	Engineer 4th Class Motor, Third Engineer
Stanway, D.	Engineer 4th Class Motor, Fourth Engineer

CSS VECTOR

Sjoholm, K.	Master, F.G.; Master
Price, G.	Master, H.T.; 1st Officer
MacKenzie, R.	Mate, H.T.; 2nd Officer
Vacant	Chief Engineer
Pearson, R.	Engineer 3rd Class Motor, Second Engineer
Conway, A.	Engineer 4th Class Combined,, 3rd Engineer.

CSS RICHARDSON

Wheeler, M.G.	Master, H.T.; Master
Henderson, J.N.	Engineer 4th Class Motor; Chief Engineer

MV RADIUM EXPRESS

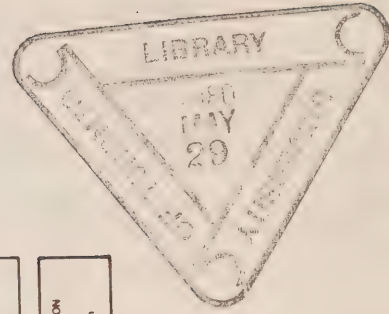
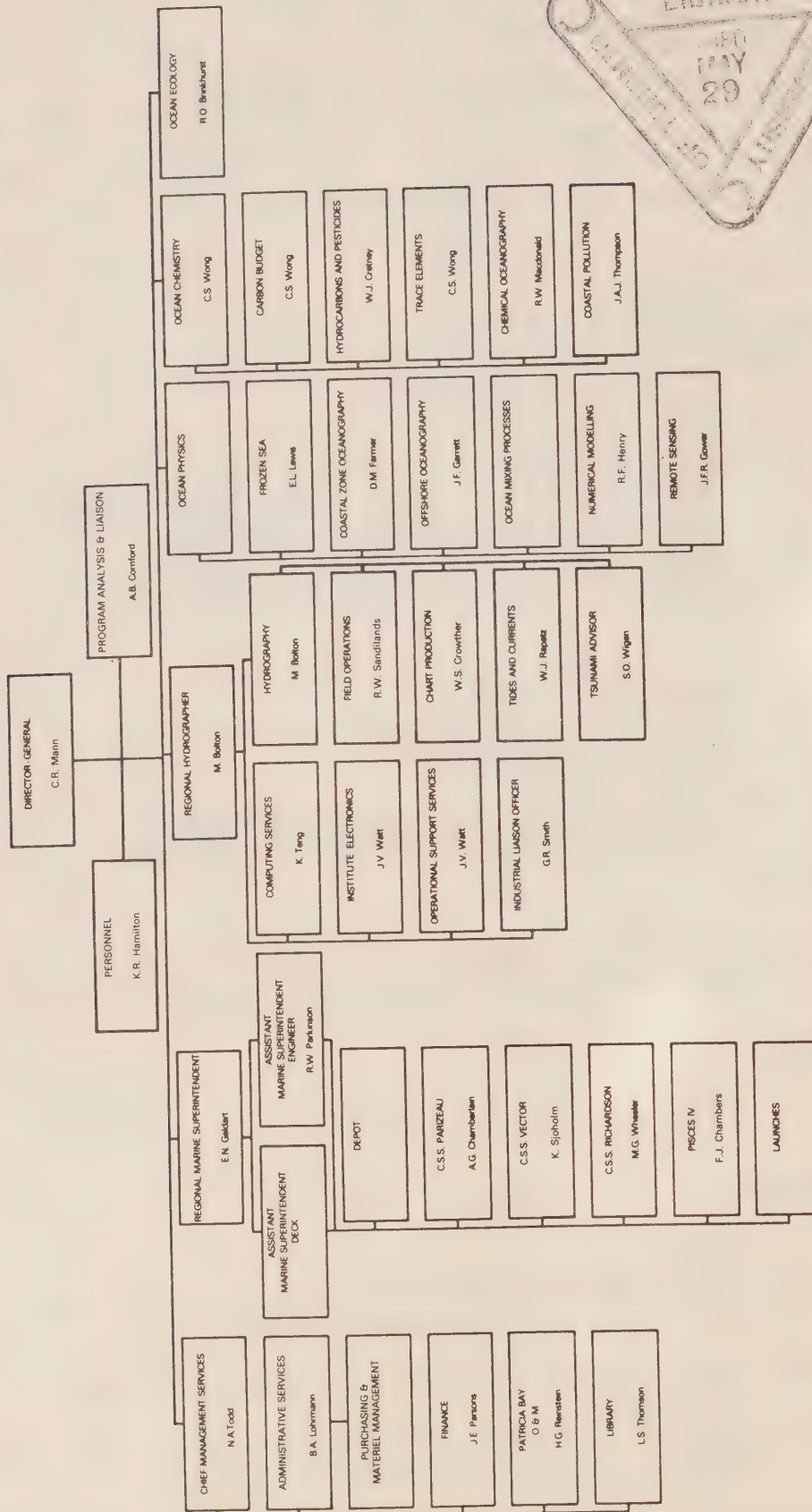
Wiebe, I.	Master
Boudreau, N.	Chief Engineer

MV PANDORA II (Charter)

Jones, R.	Master
Newton, J.	Chief Engineer

PISCES IV

*Sanderson, I.	Chief Pilot
Chambers, F.J.	Chief Pilot
Taylor, R.H.	Pilot
Evans, D.	Pilot
Witcombe, A.	Pilot



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1980 ANNUAL REPORT

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1980 ANNUAL REPORT

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Director-General's Foreword

This annual report is intended to provide a general overview of activities at the Institute of Ocean Sciences during 1980, the first year for which all departments and sub-divisions have joined in producing a single, comprehensive outline of our work.

One of the more fortunate events of 1980 was a decision by the Atmospheric Environment Service to second a senior research scientist here, to work with our staff on problems of mutual interest. The first such co-operative endeavour was the Storm Transfer and Response Experiment, field work for which was completed during the year; it is more fully described later in this report. It is my hope that this initial step will lead to the development of a meteorological component at the Institute, since our oceanography programs are already closely linked with meteorological problems.

During the year, formal reviews of our Oceanography and Hydrography programs were conducted by outside review groups. These outside groups have provided perspectives which can not be obtained through internal review processes. Their conclusions will be used to develop the Institute's staff, and in planning our program strategy. We intend to continue with such reviews.

1980 also saw the formation of the Ocean Information Division, which was established to provide reviews and advice to agencies concerned with protection of the environment. In addition, this new division will generate raw data and printed materials, such as atlases. It is our further intention that the Ocean Information Division anticipate marine environmental problems, providing the necessary overview and assessment before situations become urgent. For example, work has already begun on a study of marine environmental problems in the Beaufort Sea, which has been targeted for extensive oil exploration. All activities of the Ocean Information Division will be based on the expert advice of our research staff.

The Pacific Region of Ocean Science and Surveys was reorganized in 1980, following the retirement of several directing staff members. Our organization is now based on the principle that technical facilities should be operated by the divisions which are their primary users, and should not be centralized. Accordingly, Ships and Electronic Services have been placed under the Director of Hydrography, and Computing Services under the Head of Ocean Physics.

Perhaps the most gratifying development of the year, from a director's point of view, has been the spontaneous emergence of joint research

among scientists from various departments here at IOS. It is this kind of co-operative research which the Institute was created to foster; to see it developing is reassuring, and augurs well for the future.

DEPARTMENT OF FISHERIES AND OCEANS

Hydrography

The main objective of the Hydrographic Division is to provide accurate, timely bathymetric and navigational information in the form of nautical charts, tide tables, and sailing directions for all types of users—commercial shippers, fishermen and recreational boaters. Additional data are provided to other federal government agencies, engineering and consulting firms, universities, environmental groups, and the general public.

The Division carried out three major activities during 1980: surveys of the Beaufort Sea and associated development projects; a reorganization of the Chart Construction group; and participation in the Coastal Ocean Dynamics Experiment (CODE).

A design contract for a vessel to replace the CSS *William J. Stewart* was let to a Vancouver firm of naval architects. Special funding provided for a long-range positioning system, an onboard computer, new echo-sounders, and digitizers to refurbish the aging hydrographic equipment.

In October, a formal program review and evaluation of hydrographic activities was carried out by an independent review team comprised of representatives from industry, universities, and other government agencies. This was the first of its kind for IOS hydrography, and proved both informative and constructive.

Field Hydrography

Field Hydrography is responsible for conducting hydrographic surveys of B.C. coastal, western Arctic, and navigable inland waters of the Pacific Region, in order to ensure that requirements for navigational information are met. Alterations of and additions to traffic routes, types and sizes of vessels, harbours, bottom topography and coastlines— all these require an ongoing survey and resurvey program.

*Barge Pender and launches in
Barkley Sound.*



The barge, *Pender*, designed primarily as a tender for the submersible, *Pisces*, was assigned to hydrographic field surveys for the first time during a three-month period in 1980. It was towed to the Broken Group in Barkley Sound on the west coast of Vancouver Island in late April. The Broken Group area was last surveyed, by lead line, in 1931. These waters are now part of the Pacific Rim National Park. In addition to steadily increasing recreational activity, there are several channels for coastal commercial traffic in Barkley Sound. After this project was completed, the survey party moved to Okanagan Lake for the balance of the season. (For additional information regarding these surveys, contact G.E. Richardson.)

Work was also conducted from the CSS *Richardson* in the Queen Charlotte Islands, in areas last surveyed early in this century. Surveys of Masset Sound, McIntyre Bay and Virago Sound were completed. Naden Harbour and an area in Dixon Entrance between Seath Point and Wiah Point were resurveyed. Some preliminary work was done in Skidegate Inlet, the new terminal area for the B.C. Ferry Service to the Queen Charlotte Islands; a complete resurvey is scheduled for 1981. (Contacts: M.V. Woods and C.R. Tamasi.)

While in northern waters, the *Richardson* party assisted federal Ministry of Transport (MOT) personnel investigating the loss of the ore freighter, *Lee Wang Zin*. The *Richardson* surveyed Celestial Reef in Dixon Entrance, in order to confirm its precise location and depth.

Several shore-based surveys were carried out on the B.C. coast to assist planning for new charts. Coverage of a large area near Swartz Bay was further extended for a proposed new chart. Areas in the vicinity of Campbell River and Cowichan Bay were resurveyed at the request of MOT. The Pacific Pilotage Authority asked that Romulus Rock in Porlier Pass be resurveyed. As well, an area around Patey Rock in Satellite Channel was resurveyed in order to resolve conflicting data.

Pandora II, a charter vessel, left for the western Arctic at the end of June. Although an early entrance to the Beaufort Sea was achieved on July 18, ice conditions hampered survey operations for the entire season. In early September it was decided to leave before the western exit to the Beaufort Sea was closed by ice. Unfortunately, the vessel developed steering problems, which meant returning to Tuktoyaktuk for repairs. By the time these were completed, passage out of the Arctic had to be made eastward via the Northwest Passage, since there was no icebreaker support to assist a westerly departure around Alaska. The voyage ended at the Bedford Institute of Oceanography (BIO) in Dartmouth, Nova Scotia. (Contact: A.D. O'Connor.)

The CCGS *Bernier* ran profile track soundings in Minto Inlet and Prince Albert Sound for potential beach landing sites. (Contact: J.A. Vosburgh.)

Aerial surveillance of artificial oil drilling islands in the Beaufort Sea continued during 1980; the future of this program is under evaluation.

The Navigation Group tested a Minifix positioning system on the *Pandora II* in case a new system planned for the HUDSON '81 hydrographic surveys in the Beaufort Sea next year is not available. The Navigation Group also provided support to the Pacific Geoscience Centre (PCG) by collecting bathymetry for resource charting surveys off Dixon Entrance, using the BIONAV data collection package.



Hoisting a Minifix mast at Pullen Island, N.W.T.

The Navigation Group also entered a cooperative venture with Dome Petroleum Limited and the federal MOT to assess Loran-C Accufix systems as possible navigational aids to tanker traffic in western Arctic waters. (*Contact: A.R. Mortimer.*)

Surveys for revised charts and sailing directions in the Fraser River, Vancouver Harbour, the Strait of Georgia, and for charts covering all of Vancouver Island, were carried out under contract.

A great deal of planning has gone into the hydrographic phase of the HUDSON '81 expedition. One of the major projects to be undertaken is a corridor survey through the Pingo-Like Features (PLF) area of the Beaufort Sea. Pingos are known to exist in depths of 20-100 m off the Tuktoyaktuk Peninsula. They are a major navigational hazard to the deep-draught tankers which are expected to transit the Beaufort Sea in the foreseeable future. The traffic corridor being planned is ten miles wide and 170 miles long; it will take several seasons to complete all survey work. The first surveys will be done by the CSS *Hudson* with hydrographers from the Pacific Region in charge, assisted by staff from headquarters and the other regions.

Sailing Directions

The Sailing Directions Section maintains two volumes each of sailing directions and small craft guides for the B.C. coast. New editions of these double volumes are published every other year.

The third edition of *B.C. Small Craft Guide: Volume II, Boundary Bay to Cortes Island* was published in July. *Sailing Directions for Kootenay Lake and River*, a strip chart with directions in book format, was published in May. A new edition of *B.C. Sailing Directions (North Portion), Volume II* is in the final stages of preparation and will be published in 1981. It will be followed by a new edition of *B.C. Small Craft Guide, Volume I: Vancouver Island, Port Alberni to Campbell River, including the Gulf Islands*.

Hydrographic Development

Preparatory work was undertaken for acquisition of a new computer and associated equipment to be installed aboard the *Hudson* for the 1981 Beaufort Sea survey program. Software packages for general survey and Loran-C computations on the HP9825 computer were completed and documented. Other activities included: revised sounding selection algorithm for the hydrographic data processing package; restructuring of plotting routines for survey lattices; and incorporation of B.C. provincial data for the Okanagan Lake survey.

Coastal and shoreline features from recent topographic maps at a scale of 1:5,000 were redrawn at the survey scale of 1:40,000, using the automated cartographic plotting system. A minimum of field work was required to verify the quality of the data, resulting in a considerable saving of time when compared with a conventional survey of the entire area.

Work continued on the Aerial Hydrography Project at the Canada Centre for Remote Sensing in Ottawa. In conjunction with the Central Region, ground control points were established for a photo mission along a portion of the Bruce Peninsula on Lake Huron. This contract has been completed; recommendations for future activity are under review.

During the year, two international hydrographers, Mr. Hideo Fukaya representing the Japanese Hydrographic Association, and Lieutenant Garcia from the Portuguese Hydrographic Institute, visited IOS to examine the hydrographic data system in use for the Pacific Region.

Chart Production & Distribution

Chart Production and Distribution have two major functions: to process survey and other data into new charts and publications as quickly as possible; and to ensure that an adequate stock of corrected charts is readily available for all users of Canada's navigable waters, as required by law.

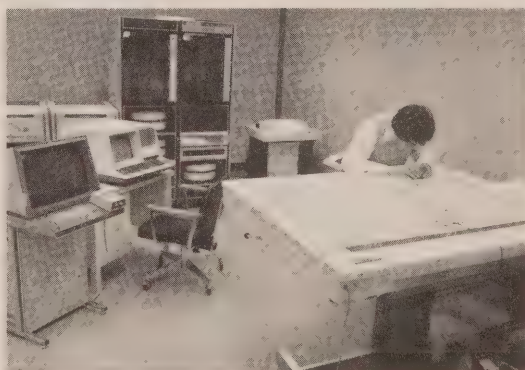
The regional program includes the compilation, drafting and distribution of nautical charts. In Chart Production, emphasis is being shifted from New Editions to New Charts, reflecting an accelerated conversion to a standard metric/bilingual format. The Distribution Section is planning more aggressive promotion of charts and publications, to increase public awareness and use of them.

By mid-1980, Chart Production was near full strength for the first time since decentralization was initiated. A reorganization of the production units now ensures training and development of cartographers in every area. Cartographers in each unit are required to take turns preparing new charts, editions and reprints, and using automated equipment.

Due to the lead time required for the production of new charts, the impact of the decision to shift from chart maintenance to new chart production will not become evident for several years. Extensive work is underway in developing chart schemes and formats for the western Arctic, and in new proposals for coverage of the Queen Charlotte Islands. Minor changes for large areas adjacent to Johnstone Strait are also being considered.

Four new Pacific Region Charts were produced in 1980, three by the Region and one at Headquarters. In addition, 49 new editions (including one by Headquarters), 45 reprints (24 by Headquarters), three overprints, six patches, and 96 notices to mariners were completed.

Cartographer's Digitizing Station.



The past year has seen relatively few development changes in Automated Cartography. One new Headquarters program, SYMBOL, and three regionally-developed programs, MOSCHK, PLACES and STAR 2, have been added to our system. An ALTEK digitizing table has been ordered; delivery is expected in 1981.

Participation in the CHS Carto I Course, and rotation of all cartographic staff through the photo-mechanical unit continued with good results. Assistance has also been offered to the new cartography program at Camosun College, Victoria. Chart Production will provide the college with guest lecturers, equipment, materials, and assistance with projects.

The number of documents now stored by the Technical Records Unit is approximately 30,000. One of the primary tasks of the Nautical Information Officer and the Technical Records Clerk is the collection of data from every possible source. The increasing demand for nautical information, especially Notices to Mariners and Notices to Shipping, has resulted in the appointment of a temporary assistant to the Navigation Information Officer. A close rapport continues with the Canadian Power Squadrons, which submitted 450 MAREP reports. These, in combination with information from numerous other sources, contributed to 1,630,339 corrections to 272,981 charts completed by contract in 1980.

During 1980, the Chart Distribution Office expanded its program of advertising new charts and publications to authorized dealers and the boating public. A computerized system for informing dealers of new printings and other products was instituted, along with a new Chart Dealer Poster, 23 new sales outlets and 11 small craft guide dealerships were added to the distribution network in 1980. Pacific Region distributed 196,579 charts, 84,601 publications, and 8,157 free pamphlets and brochures.



I.O.S. Retail Sales Office.

Tidal and Current Surveys

This program provides tidal, current and water level data, along with other information and expertise, for the Canadian west coast and western Arctic. Instrument field networks are maintained for operational and research purposes.

The past year marked the end of field operations for tides and currents in the Coastal Ocean Dynamics Experiment (CODE) off the west coast of Vancouver Island. All but one of 15 offshore, and seven near-shore moorings were recovered. However, the task of analysing some 175 data records from current meters and bottom-mounted pressure gauges, spanning about 16 months, continues. The successful use of pinger batteries built at IOS, with a life in excess of two years, has also been demonstrated. (*Contacts: W. Crawford and S. Huggett.*)

During the Storm Transfer and Response Experiment (STREX) in October, 16 buoys for measuring current shear, salinity and temperature were deployed from CSS *Parizeau* for participating Canadian and American agencies. (*Contact: S. Huggett.*)

A current meter was installed at Race Rocks in the Strait of Juan de Fuca near Lester B. Pearson College, which carries out marine biology studies in that area. The records obtained will result in predictions for Race Passage, to be included in Volume 5 of *Canadian Tide and Current Tables*. A study of entrainment processes, in conjunction with the University of Washington, and mathematical modeling of the Fraser River and its salt wedge, are both continuing.

Final tests of airborne electronic oil spill markers were carried out in the Strait of Juan de Fuca, in co-operation with the Remote Sensing Unit of IOS. These markers were parachuted onto the sea surface and monitored from an aircraft in order to map surface currents. This technology is now being commercially marketed in Victoria. (*Contact: A. Ages.*)

Data collection and marigram processing from permanent and temporary tide gauges continues. The permanent gauge in Vancouver Harbour was suddenly discontinued by construction work. It was replaced with a temporary gauge, resulting in a minimum interruption in one of our longest tidal data series. A new gauge on Ballantyne Pier, Vancouver, will be operational in 1981.

Temporary gauges were placed at Gold River, Tahsis and Zeballos for a co-operative project with Pacific Geoscience Centre (PGC) to determine possible tilting of Vancouver Island.

Eleven pressure gauges placed in the western Arctic's Coronation Gulf, Queen Maude Gulf and St. Roche Basin in 1979 were recovered in

the summer of 1980. The gauges were used to record water level and barometric data, which are currently being interpreted.

Diving Unit

Staff members at the Institute of Ocean Sciences provide a diving service in support of Institute programs, in addition to performing their regular duties. Only those possessing the desire to dive, the necessary mental and physical capabilities, and the proper training are permitted to carry out diving operations. Such operations have become an integral part of most modern oceanographic establishments.

In 1980, over 150 dives were made on the Pacific Coast and in the western Arctic, which is comparable to the preceding year. IOS divers assisted in the deployment of three Controlled Ecosystem Enclosures (CEE) in Patricia Bay, near the Institute. Seven Institute divers, assisted by three contract divers, participated in this successful launch. The Diving Unit was also involved in: deploying and recovering numerous pressure gauges and moorings for the Coastal Ocean Dynamics Experiment; taking sediment cores; testing new current meter systems; and conducting ship hull inspections, some in western Arctic waters. (*Contact: F.E. Stephenson.*)

Tsunamis

Systematic efforts are being made in Canada and other Pacific Rim countries to provide earlier and more accurate warning when a threatening tsunami has been generated in the Pacific Ocean. Attention is being given to educating the public about the impact that tsunami waves may have on coastal areas, and the need for evacuation when warnings are issued. Instruction is provided to civil agencies responsible for dealing with a tsunami emergency.

These subjects were major agenda items at the 1980 meeting in Chile of the International Coordination Group for the Tsunami Warning System in the Pacific. Locally, the British Columbia Earthquake and Tsunami Working Group sponsored a seminar for the Association of Vancouver Island Municipalities, to inform civic officials of the tsunami and earthquake problems for which their communities need to be prepared. A command post exercise was conducted to test tsunami watch and warning procedures.

In addition to participating in these operations, the IOS Tsunami Unit has continued to develop its research base. During 1980, visits were made to tsunami research institutions in several Pacific Rim countries.

A historical study and computer record of tsunamis in the Pacific is being co-ordinated on behalf of the International Tsunami Information

Centre. The statistical basis for forecasting frequencies and magnitudes is being improved. (Contact: S. Wigen.)

Engineering Services

Engineering Services provide electrical, mechanical and technical support for survey, research and ship operations conducted by the Institute.

Electronic Engineering Group

1980 saw the completion of a computerized carbon dioxide gas analyser system. The first major phase of the Acoustic Doppler Current Profiler was completed, and the instrument was used to gather oceanographic data in Knight Inlet and Georgia Strait. SAIL, a system which provides detailed real-time ship's data to scientific users, was successfully tested on CSS *Parizeau*. A shipboard data logging system and acoustic navigation package for the submersible, *Pisces IV*, and a depth digitizer for the HUDSON '81 program were developed by contract.

This year, too, the Electronic Engineering Group undertook a variety of hydrographic projects in conjunction with the High Arctic Research Program, including the development of a side-scan sonar, study of a side-tow sounding system, and a variety of data processing developments.

Technical Support Group

During 1980, this group was involved in the *Pandora II* western Arctic survey and several west coast surveys, including Barkley Sound with the *Pender*, and northern Queen Charlotte Islands with the *Richardson*. Shore parties were also conducted at Okanagan Lake, Campbell River and the Sidney-Swartz Bay area.

Other projects included: the design and construction of two uninterruptable power supplies; modifications to Mini-Fix in preparation for Arctic trials; fitting out the launch, *Nucleus*, for the Barkley Sound survey; installing a third radio station in the *Pender* for hydrographic purposes; preparations for HUDSON '81; and equipment acquisition and evaluation. Adaptation of low-cost commercial fishing echo sounders to hydrographic purposes is under contract.

Mechanical Support

This group provides machining and fabricating facilities, in addition to engineering design assistance for IOS. Projects vary from repairs and modifications to the design and construction of prototype devices. 1980 achievements include:

- trace metal seawater sampler (for Ocean Chemistry)
- component parts for CTD (conductivity, temperature, depth) winches (Frozen Sea Research Group)
- hydraulic piston assemblies (Ship Division: *Pisces IV*)
- aluminum core masks (Ocean Chemistry)
- pressure transducer connector and penetrator (Ocean Ecology)
- PVC seawater samplers (Ocean Ecology)
- pressure vessel for diving gauge testing (Tides and Currents).

Industrial Liaison and Contracting

The Institute of Ocean Sciences has an established policy of conducting a significant portion of its program through contracts to the private sector. Liaison and support for contracting activities is conducted by the administrative staff of the Engineering Services Group. The level of contracting activity did not quite achieve the \$2.2 million level of 1979. However, expected increases in the Ministry of Transport-administered High Arctic Research Program (Hydrography) and IOS participation in the National Research Council's Program for Industry/Laboratory Projects (PILP) suggest a possible 15-20% increase in contract activity for 1981/82. (Contact: J.V. Watt.)

Oceanography

The oceanographic program includes ocean physics, ocean chemistry and ocean ecology. The Institute of Ocean Sciences is responsible for conducting research and providing advice in many areas, including: ocean processes, operations in ice-covered waters, ocean resources, marine pollution, and the ocean's influence on climate and the effect of that relationship on human activities.

The oceanographic program contributes to the development and transfer of ocean technology, the provision of ocean information, ocean data management, and to marine research at universities and other institutions throughout the world. Areas under study include coastal, shelf and offshore waters of the Pacific, as well as a significant portion of the western Arctic, including the channels of the Arctic Archipelago.

Ocean Physics

During 1980 it became apparent that the Institute as a whole, and the Ocean Physics Division in particular, had reached an exciting new stage. Mutually beneficial working relationships between members of different groups are become the rule, so that projects involving only members of Ocean Physics have become rare. Such relationships extend outside the Institute, to other Canadians and scientists around the world. The resulting exchanges have had a stimulating effect on all those involved, and this has in turn communicated itself to the rest of the staff. The end result is a more lively intellectual atmosphere than was previously evident.

A list of major accomplishments during the year would certainly include: the successful completion of the polynya experiment to measure heat transfer through open water areas during the Arctic winter; the conclusion of the main part of the study of the continental shelf off Vancouver Island; and the completion of the observational phase of the Storm Transfer and Response Experiment (STREX) around Ocean Weather Station P (50°N, 145°W) during a suitably stormy November and December.

The primary objectives of the Ocean Physics program are to describe and understand physical properties, processes and other phenomena in estuaries, coastal seas and marine waters, on the continental shelf and offshore, in both open and ice-covered areas. Activities are designed to provide expert physical oceanographic information and advice to meet Canadian federal responsibilities, with particular emphasis on the west coast and the western Arctic.

Coastal Zone Oceanography

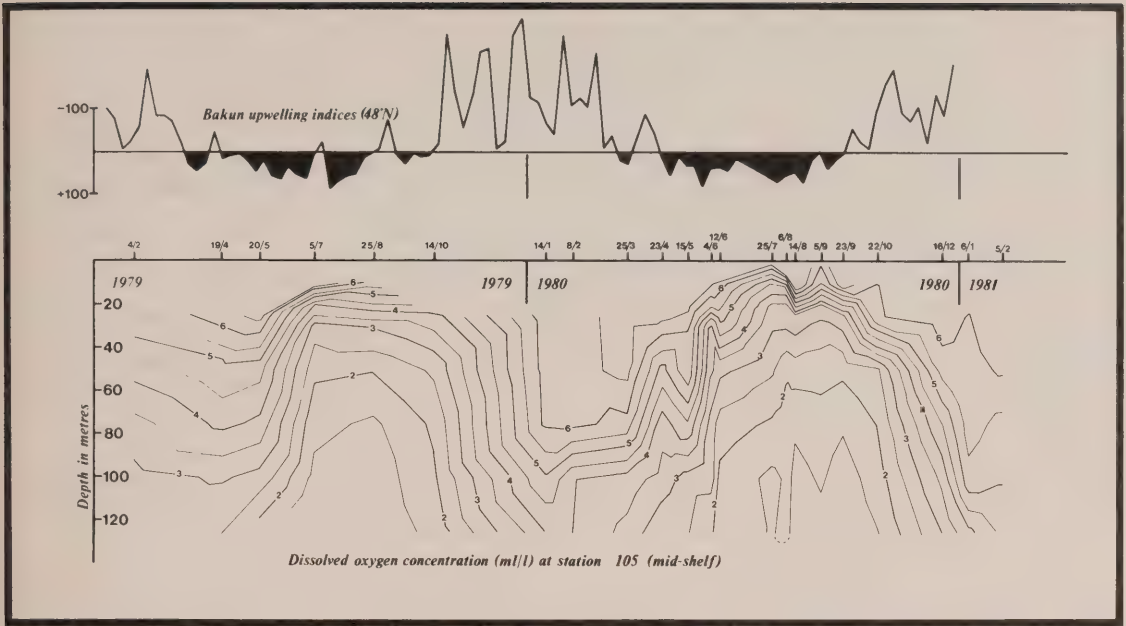
The major aim of the coastal oceanography program is to advance our understanding of coastal ocean dynamics, and of mixing processes and their consequences. Phenomena investigated include: tidal interaction with fjord sills; generation, propagation and decay of non-linear internal waves; and the structure of free shear layers and mixing processes in a salt-wedge estuary. Studies of currents and water properties on the continental shelf are conducted to increase our knowledge of seasonal and short-term dynamics (upwelling, coastal currents, long internal waves, etc.), as well as shelf water interaction with shore and inlet waters.

Continental Shelf Study

The main experimental effort of Coastal Zone Oceanography was directed to the line of seven stations extending from the continental shelf break into Alberni Inlet. A regular pattern of CTD stations and five current meter locations have been maintained off the west coast since the spring of 1979. These serve to describe the annual cycle of currents and other hydrographic properties on the southern British Columbia continental shelf.

A low oxygen event first observed in the 1979 study recurred in 1980 and was thoroughly surveyed in both space and time. This feature appears to be closely associated with a large cyclonic eddy that occurs on the southern Vancouver Island continental shelf every summer. The shelf is deeply cut by a narrow canyon, which is in such a position that the eddy induces an inward pressure gradient. We hypothesize that this gradient allows deep water to flow from depths of around 350 m at the edge of the shelf, up along the canyon bottom to the continental shelf.

The current meter aspect of the program has proceeded well. Data return for 1980 is well over 90%, and preliminary analysis shows that the flows over the shelf are complex. However, regularity can be seen at low frequencies, and an understanding of a flow pattern is emerging. The summer current pattern is consistent with the motion of the cyclonic eddy mentioned above. We have verified that locally-driven upwelling indeed occurs at this latitude, and that the intensity of upwelling is in fair agreement with theory. However, the rate of upwelling indicated by theory and experiment is not sufficient to account for the volume of dense water that appears on the shelf each spring. (*Contact: H.J. Freeland.*)



Time series of dissolved oxygen concentration (in ml/l) versus depth at a single Coastal Zone Oceanography Station on the continental shelf off Barkley Sound, through 1979 and 1980.

The annual signal is dominated by a period of extremely low dissolved oxygen values through the summer period. The time of onset of the feature (in 1979) does not appear to be closely related to any specific event in the weather record, above the contour plot; but the time of collapse appears to be close in time to the occurrence of the first major storm of the winter.

The plot above is a Bakun Upwelling Index of 48°N. This is an estimate from geostrophic winds of the magnitude of the coastal wind field. Specifically, it is the computed transport offshore in the surface Ekman layer in $\text{m}^3/\text{sec}/100 \text{ m}$ of coastline length.

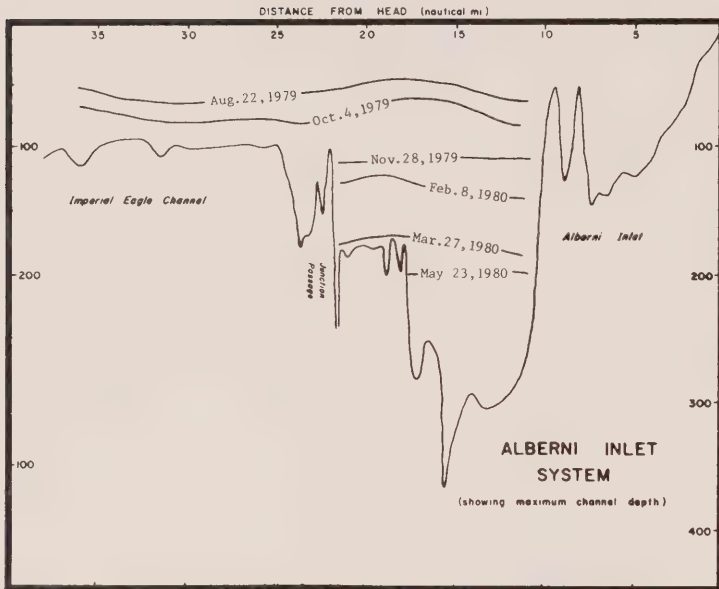
Alberni Inlet Circulation Study

A related program which includes two additional meters extends from Barkley Sound into the Alberni fjord system. CTD and oxygen data were collected on a series of cruises at about six-week intervals. The shelf water appears to play a major role in the renewal of deep basin water, resulting in nearly complete replacement annually. This was confirmed once more by the 1980 data defining the water structure, although the periods of strong steady inflow of deep waters observed in 1979 were not so much in evidence.

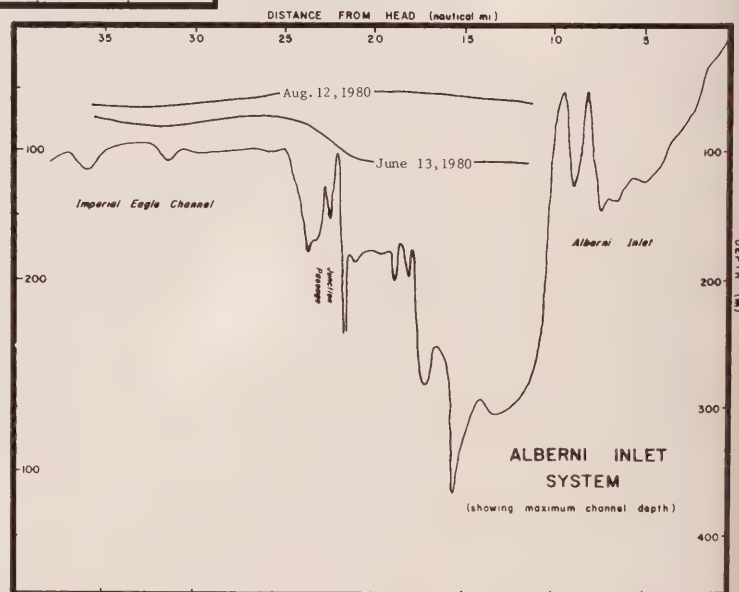
A decrease in oxygen content was observed, following an initial increase, as dense water continued to flow into the fjord. Above sill depth at the outer basin mooring, strong (0.4 m/s) and frequent (3-10 days) exchanges of water between fjord and shelf were observed,

especially during the late fall and winter months, when the frequency and intensity of weather disturbances are greatest. These exchanges appear to be controlled by the offshore wind field, since the direction of the exchanges is correlated with upwelling indices for the adjacent region.

Changes in the shelf density structure produced by wind stress cause a rapid readjustment to the fjord density above sill depth. Plans are presently underway to construct a numerical model of shelf-fjord interaction. (Contacts: W.H. Bell and D.J. Stucchi.)



This figure shows sequential positions of an isopycnal ($\sigma_T = 25.4$), indicating the annual cycle of density changes in the deep outer basin of Alberni Inlet, B.C. The gradual descent of constant density surfaces through fall and winter, and the relatively rapid uplift in late spring, are readily apparent.



Acoustic Velocity Sensor

A sonar device for remotely sensing currents at depths to a few hundred metres has been built and tested. The system uses the range gated Doppler technique, although other approaches are also being considered. In its present configuration, the 100 KHz transducer is mounted on a steerable platform at the base of a ship-mounted mast; data have been collected with the ship both travelling and stationary. Several tests in Knight Inlet and Saanich Inlet confirm the feasibility of the approach, while also emphasizing some of the technical difficulties such as the generation of suitable beam patterns. Development of a more advanced transducer operating at 200 KHz with a much narrower beam and lower side lobes is presently underway. (*Contacts: D.M. Farmer, and J. Galloway of Institute Electronics.*)

Knight Inlet Circulation Study

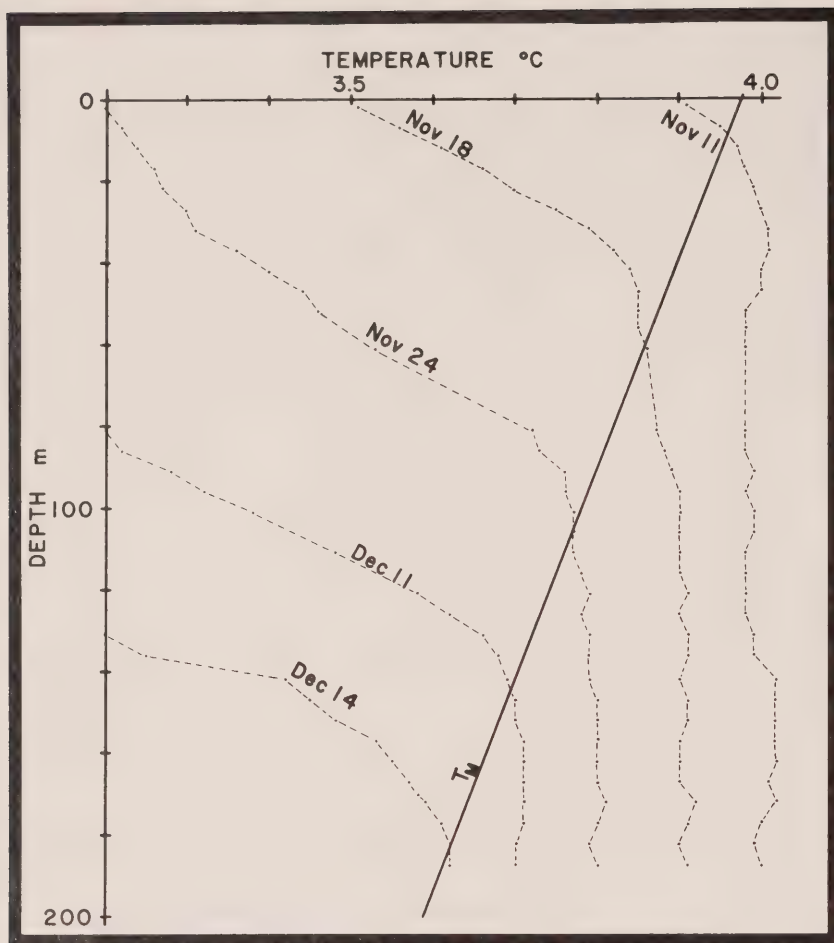
Study of the circulation of Knight Inlet continued this year in conjunction with Dr. Pond, University of British Columbia, using the automatically profiling Cyclosonde current meters. Velocity profiles were obtained simultaneously with the range gated acoustic Doppler system to permit comparison of the two techniques.

Analysis of data obtained in previous years is permitting calculations of non-linear internal wave trains generated at the sill. In particular, it has been shown that energy lost from the waves is just sufficient to account for changes in both density and velocity profiles in the fjord over the 20 km that the waves could be tracked. (*Contact: D.M. Farmer.*)

Lake Circulation in Winter

An analysis of re-stratification in a lake during winter, when it is below the temperature of maximum density, has explained the existence of several features observed in Babine Lake. An equation of state that includes the effect of pressure on the density structure shows that just below 4°C, during periods of cooling and wind mixing, a transition depth must exist, separating a zone of forced convection near the surface from free convection beneath. Mixing across this layer can occur through a conditional instability in which a downwards movement of initially stable stratified water can become unstable, resulting in convective mixing to the lake bottom. It is shown that, as the lake cools, this transition depth must increase.

A review of data collected in Babine Lake has provided direct evidence of this transition zone which marks a change between water that has



Temperature profiles obtained in a lake as it cools through the temperature maximum density (T_m) show the transition between wind mixing above the T_m curve and convective mixing beneath.

As the lake cools, the depth of the transition between these two types of mixing increases, eventually leading to a retreat of the wind-mixed layer during restratification.

This figure shows the way in which pressure has been found to influence the dynamics of a wind-mixed lake near 4°C .

been very thoroughly mixed by convection below and less completely mixed water above. As the lake cools, the transition zone deepens and the mixing layer also retreats, leaving behind the winter stratification. The observations in Babine Lake provide a testing ground for models of restratification, and provide the basis for interpretation of winter measurements taken in other lakes. (Contact: D.M. Farmer.)

Lighthouse Station Program and Task Forces

Daily salinity and temperature samples continue to be taken at lighthouse stations along the coast, and an additional set of data from Bamfield and Cape Beale have been added in the reports. Assistance was also provided to a number of task forces, and on various regional and municipal problems. (Contact: L. Giovando.)

A watching brief was continued on developments in mooring technology and related aspects, such as drag and vibration problems. Assistance with mooring design was provided to other groups in the Institute. A watching brief was also maintained on the physical aspects of ocean dumping. (*Contact: W.H. Bell.*)

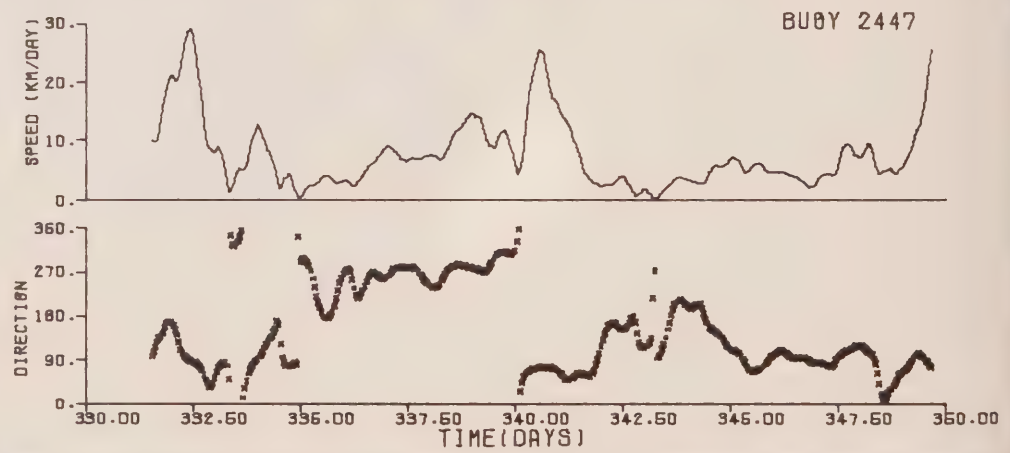
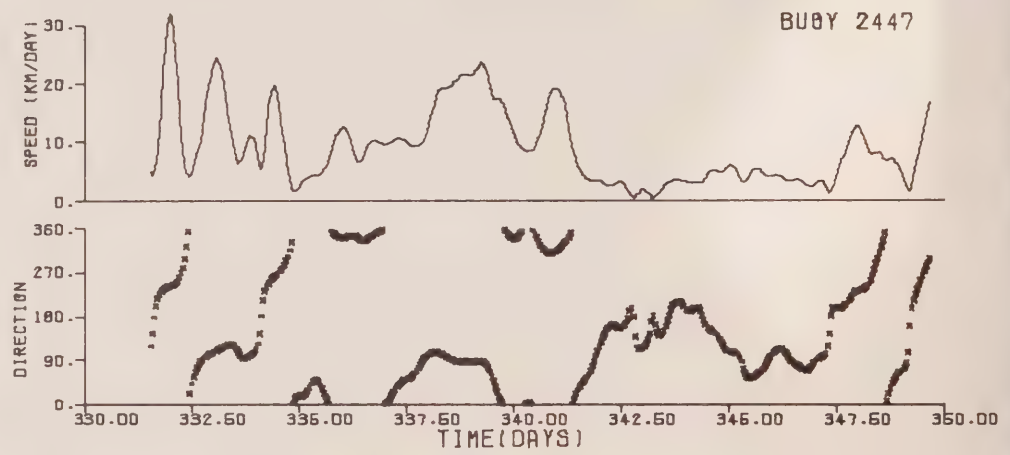
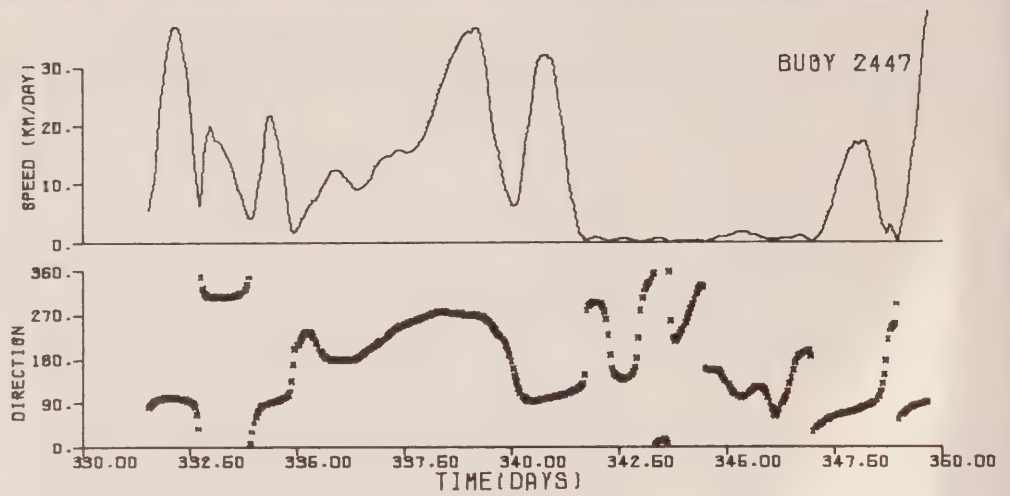
Frozen Sea Research

The Arctic physical oceanographic program concentrates on understanding processes operating in Arctic fjords and inlets, the Arctic heat budget (including air-sea-ice interactions), and the dynamics of the Arctic Ocean and channels of the Arctic Archipelago. The major objectives are to provide advice and information to government departments, Arctic industry, and the public for design and marine regulatory purposes.

Polynya Experiment

The third year of field study of the Dundas Island Polynya (76°08'N, 95°00'W) was completed during March and April, in co-operation with groups from the Bedford Institute of Oceanography and the Atmospheric Environment Service, Downsview, Ontario. Measurements were made of mean velocity and temperature profiles in the atmosphere, upstream and downstream of the polynya, together with records of the fluctuating components of velocity and temperature. Independent, preliminary analyses by all the groups involved indicate that sufficient data has been obtained to assess heat loss from the polynya over a wide range of conditions.

Oceanographic data were obtained from four Aanderaa current meters placed 12 m below the ice to record current speed and direction, water temperature, and conductivity for a period of 34 days. Complete data sets were recovered from all instruments. A preliminary analysis indicates a strong temperature signal in the water mass closely correlated with tidal flow, there being roughly a 0.1°C temperature difference between tidal flows in opposite directions. A workshop involving all three participating scientific groups is planned early in 1981. (*Contacts: E.L. Lewis and R.L. Lake.*)



Beaufort Sea Oceanography

All the four Beaufort Sea CTD profiles acquired in November, 1979, have been analysed, and a new field operation has been planned for March, 1981. The 1979 data has defined the baroclinic flow with respect to the 400 decibar level at a coarse spatial resolution (approximately 100 km). Over the continental slope, the baroclinic current is about nine cm per second, twice the current offshore. Outflow from the Amundsen Gulf was demonstrated by the baroclinic calculation, and by the existence of a sub-surface temperature maximum distinct from the Bering Sea water which was identified in the Amundsen Gulf and along the slope north of Tuktoyaktuk.

Information on currents on the shelf is very limited, and bottom-moored meters are liable to be destroyed by moving ice. For this reason, work was initiated using the positions and relative current measurements of satellite-tracked buoys equipped with current meters as they moved with the ice. Elimination of higher frequencies with the use of Kalman-Filter techniques shows great promise in enabling computation of currents at mid-depth (approximately 20 m). The group is involved in the preparation of a definitive statement of southeastern Beaufort Sea oceanography. The early stages involve a compilation and critical appraisal of all existing data. (Contacts: H. Melling and A. Cornford.)

Speeds and directions of ice drift and water movement, measured during the Beaufort Sea Winter Ice Experiment in late 1979. Data were received via satellite from a buoy, and from a current meter drifting freely with pack ice at a depth of 20m.

Careful processing of the data permitted an estimate of the ice drift (top of chart), the water flow relative to the moving ice (centre), and the actual current (bottom). An ice-moored current meter permits current measurement at shallow depths in the Arctic, where a bottom-moored meter would be destroyed by moving ice. (Data courtesy of Canadian Marine Drilling, Ltd.)



Bridport Inlet

The survey of Bridport Inlet (75°N, 108°W) continued, in order to provide sufficient additional data for testing a circulation model. This is the proposed site of a liquid natural gas tanker terminal for the Arctic Pilot Project. Initial evidence indicates that water movement in the entrance to the inlet appears to be considerably more complex than had been anticipated.

Oil Well Blowout Studies

Studies of the physics of deep oil well blowouts continue. The work carried out under contract by the University of Calgary on hydrate formation in natural gas bubbles formed in such a blowout has been completed. Further independent work under their post-graduate studies program has provided data on the rate processes controlling the formation of gas hydrates under a wide variety of conditions. This information has been incorporated into a mathematical model of rising bubbles which gives reasonable quantitative agreement with experimental results.

The model predicts the radius of a gas bubble as a function of time from release under specified conditions. There is a critical release depth from which a bubble just reaches the surface, and this has been used in comparing theory with experiment. These calculations can be extended to predict the behaviour of the entire bubble plume, hence to define more closely depths below which blowouts will not cause large-scale vertical circulation in the water column. (*Contact: D. Topham.*)

Technical Development

Construction of the "salinity sucker", a device for measuring ice crystal contact and supercooling in seawater, was completed and deployed in conjunction with the polynya field operation. Conditions in the polynya and in Wellington Channel were different from those recorded in previous years; no ice crystals were found at lower depths and there was no supercooling. A more sophisticated, less cumbersome version of this device will be constructed in the future. Work on salinity chains has continued by testing various commercial embodiments of conductivity cells. An excellent cell design now seems to be available and two of the commercially available chains have been ordered for field testing next year.

Analytical field and laboratory experiments enabled faults in our original sonically oriented current meters (SOCMS) to be identified; a contract to produce an improved version has been let. Much effort has gone into the design of an airborne CTD system specifically engineered to fit into a Twin Otter aircraft. This system will enable CTD profiles to be taken at a depth of 1200 m, with sufficient data processing in real-time to enable on-site judgement. There has been an accent on redundancy in the design; spares for most of the equipment and recording systems are immediately available. (*Contact: E.L. Lewis.*)

The Practical Salinity Scale 1978 has now been adopted by all major international oceanographic organizations, and is recommended for exclusive use in reporting all salinity data commencing January 1, 1982. This completes our contribution over the past five years.

Membership in IAPSO/SCOR WG 51 on the Interpretation of CTD data has resulted in the production of a final draft of "Design of CTD Observational Programs in Relation to Sensor Time Constants and Sampling Frequencies," our part in the writing of an international manual. It has become apparent that further refinement of CTD data processing procedures in the laboratory is desirable. Other researchers have suggested that our work may have some general use in improving the quality of oceanographic observations.

The group is involved in the Eurasin Basin Experiment, a child of SCOR WG 58 on the Arctic Ocean Heat Budget, scheduled to commence in March, 1981. Preparations are afoot for a pilot project to study the feasibility of using horizontal pressure gradients in Arctic channels in order to measure currents at depths where ice is a hazard.

(Contact: E.L. Lewis.)

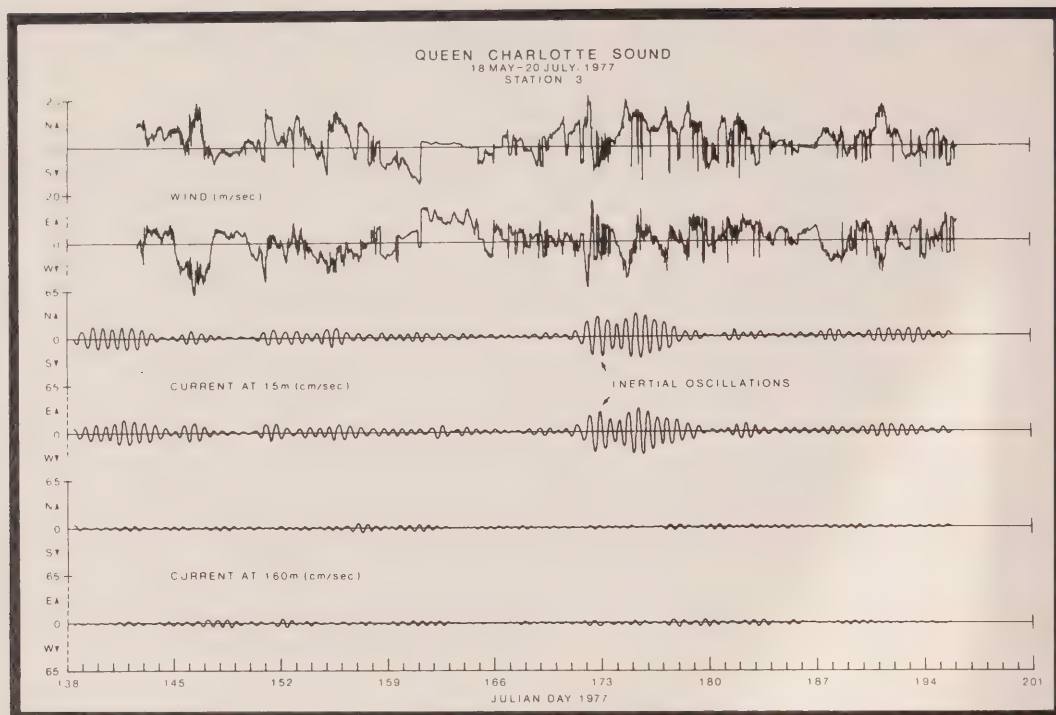
IOS chairs the Working Group on Northwest Passage Oceanography, a co-operative endeavour between industry, government and universities, for the study of this potentially important transport route. A general advisory service to government and industry provided comments on data collected by proponents and their consultants. Advisors also play an active role in committees such as the Arctic Marine Oilspill Program, Beaufort Sea Winter Ice Experiment, and the Technical Committee for the Cape Hatt Oil Spill. *(Contact: R.A. Lake.)*

Offshore Oceanography

The offshore oceanographic program studies variations of the North Pacific Ocean, in particular the distribution of ocean properties and currents, and the processes controlling them. Major areas of emphasis are: climatology and large-scale air-sea interaction; oceanography of the continental shelf; oceanic heat storage and thermal structure, and their contribution to marine weather; mixing processes and micro-structure in ocean waters; and major contributions to buoy technology for national and international programs. Inquiries are also directed towards understanding the relationship between open ocean and coastal processes.

Coastal Ocean Dynamics Experiment (CODE)

The purpose of this experiment is to provide detailed knowledge about the spatial and temporal variability of currents, winds, sea level and water properties off the west coast of Vancouver Island. The 16-month field



North-south and east-west components of the oceanic surface wind and filtered current meter records from depths of 15m and 160m. The wind components are the directions to which the wind is blowing (as per oceanographic convention).

Current components have been obtained by first removing the tidal constituents, then band-pass filtering over the inertial frequency band of 0.045–0.075 cph. Date is given in Julian days, beginning with day 138 (May 18), 1977. Station 3 is near entrance to Queen Charlotte Sound.

operations of CODE (involving Tides and Currents, Coastal Zone, Offshore Oceanography, and Ocean Ecology) were terminated in mid-September, following ocean cruises in January, May, July, August and September. Current meter losses were confined to one surface mooring, and there remains only one deep sea mooring to be recovered in early 1981.

The latter part of 1980 was devoted to editing all records and to computer plotting water property data. Preliminary results will be available by mid-1981, including reports on the distribution and variability of currents and water properties. Initial emphasis will be on the tidal currents, wind-forced shelf circulation, baroclinic tides and inertial oscillations. (Contact: R.E. Thomson.)

Queen Charlotte Sound-Hecate Strait

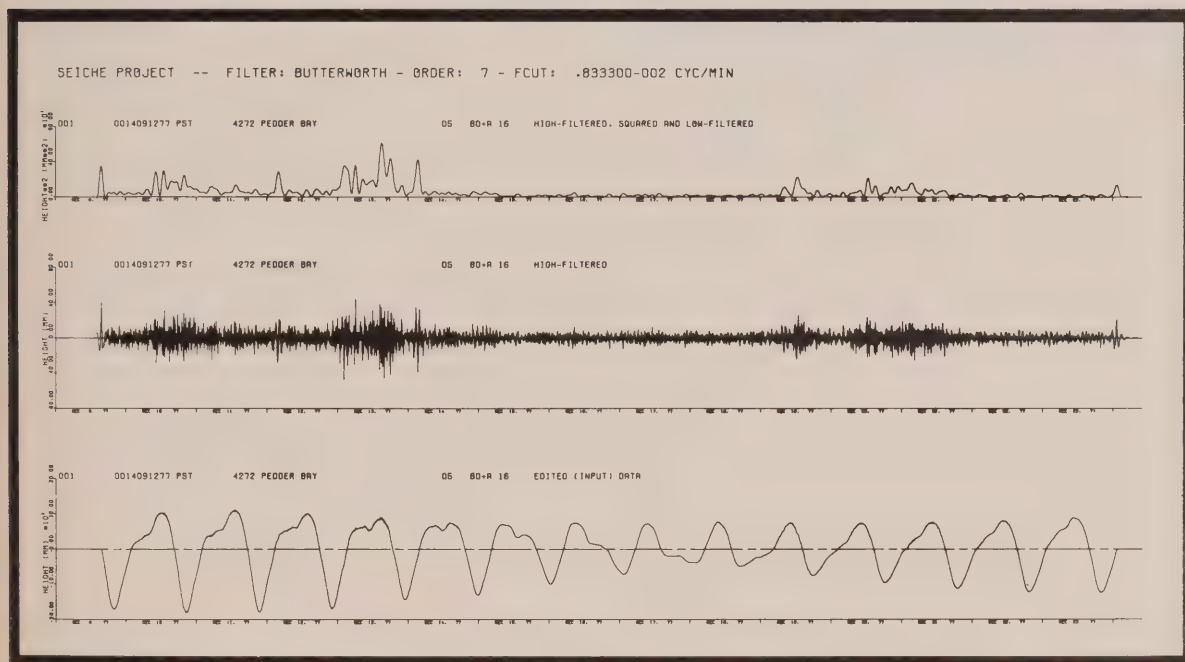
Analysis was begun on the current, wind and water property data

collected jointly with Tides and Currents from May-September of 1977 in the Queen Charlotte Sound-Hecate Strait region. Those observations also included oceanic surveys of the approaches to Douglas Channel, as part of the Kitimat oil port study. Data reports are in preparation.

One of the most interesting features observed was the presence of strong wind-generated inertial oscillations in the near-surface records. The inertial current events of mid-June and mid-August, 1977, were especially vigorous with speeds in excess of 50 cm/s, and durations of more than one week at most locations, with spatial coherences over hundreds of kilometres. Their amplitudes and phases are determined by local winds associated with eastward propagating depressions. Confinement of coastal winds by the mountainous terrain appears to account for the marked spatial variation in the inertial current patterns within the seaway. (Contact: R.E. Thomson.)

Seiches in Juan de Fuca Strait

In January and February, high resolution gauges recording at two-minute intervals were installed at Port San Juan, Becher Bay, Pedder Bay and Victoria Harbour along the northern side of Juan de Fuca Strait.



Input and output tidal height data for Pedder Bay near Victoria, B.C., from December 9-23, 1977. Lower plot is the observed tide at five-minute sampling; the middle plot is the high pass filtered tidal record; and the upper plot is the envelope of the middle plot. Heights are in millimetres.

Their purpose was to record the intermittent onset of seiche activity in each basin as part of an investigation into possible long wave propagation within the Strait. Results from similar research at Pedder Bay in 1978 suggest that the seiches, which have periods of 15-30 minutes and amplitudes of 10 cm, may have been generated by motions associated with a travelling broad-band signal originating offshore. Timing errors have proven to be a problem and the data are still being analysed.
(Contact: R.E. Thomson.)

Temperature Fine-structure and Meso-scale Frontal Regimes

Temperature observations obtained by Canadian weatherships at 13 Line P stations for the period 1969-77 show evidence for two quasi-permanent meso-scale frontal regimes west of Vancouver Island. Findings are based on vertically-smoothed digitized CTD profiles and normalized variances for temperature fine-structure with vertical scales of 20-50 m. A major frontal boundary crosses Line P in the vicinity of 130°40'W longitude to depths of 700-1300 m. Over certain depth ranges, location of the front varies seasonally, with a tendency for it to be further offshore in winter than in summer. There is also some suggestion of a secondary, poorly defined frontal boundary in the region of 136°-139° W longitude. These features serve to delineate the extent of water masses occurring off the west coast which are of particular interest for fisheries and meteorology. (Contact: R.E. Thomson.)

Vancouver Harbour Currents

The final current survey of the approaches to Vancouver Harbour's First Narrows was completed in June, in conjunction with Tides and Currents. In a manner similar to the CSS *Vector* cruises in April, June and December of 1979, time grids of 25-hour time series current and CTD stations were occupied at the east and west approaches to the Narrows. Using acoustic current/CTD profiles and a shore-based trisponder ship positioning system, "snap-shots" of water properties and horizontal currents were obtained at hourly intervals. These, together with previous data sets, will be used to determine the seasonal variability of the three-dimensional current flow through the Narrows. (Contact: R.E. Thomson.)

Steric Sea Level off the Pacific Coast

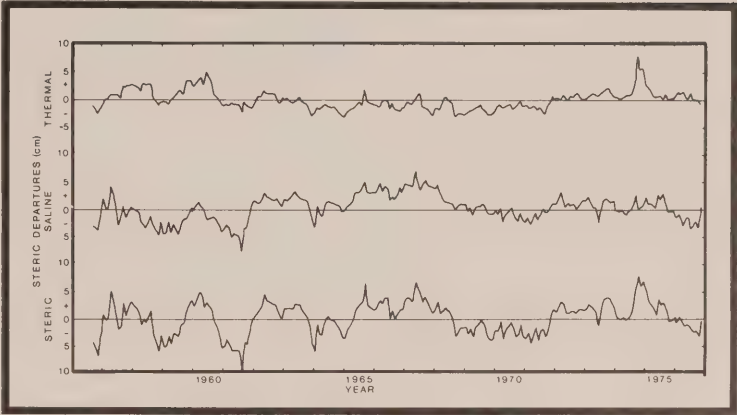
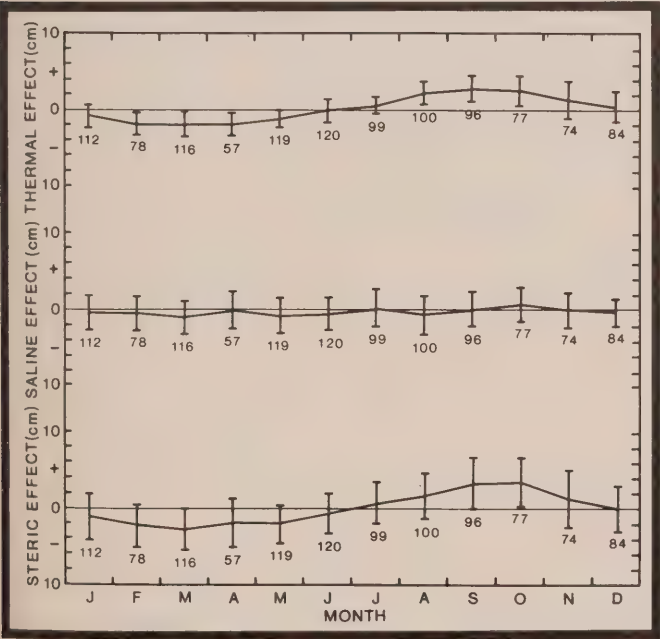
Hydrographic and CTD data taken at Station P and Line P over a 20-year period (1956-76) have been examined to determine variations of

the steric sea level (similar to dynamic height) and, in particular, to ascertain the relative contribution of thermal and saline effects. A well-defined annual cycle of steric level is evident at Station P and along the entire length of Line P. However, while the maximum height in the open ocean is reached in late summer, and the minimum in late winter, the reverse occurs over the continental shelf.

The annual cycle over the open ocean is controlled predominantly (80%) by the thermal effect. On the other hand, over the shelf it is determined primarily (90%) by a saline effect. In other words, the steric level in the open ocean is related to the annual warming and cooling of water, whereas over the continental shelf it is associated with the coastal

Steric sea level (cm) relative to 1000 m depth at Station P. The annual cycle of steric level (6.0 cm) is controlled primarily by the thermal effect. A similar cycle is evident at all stations in the open ocean, except over the continental shelf, where the cycle is 180° out of phase. There, the salinity effect predominates. (Numerals denote numbers of observations.)

▽



△

Anomaly of steric sea level (cm) at Station P for 1956-76. Both thermal and salinity effects, the latter being more influential, contribute to the variability of the level.

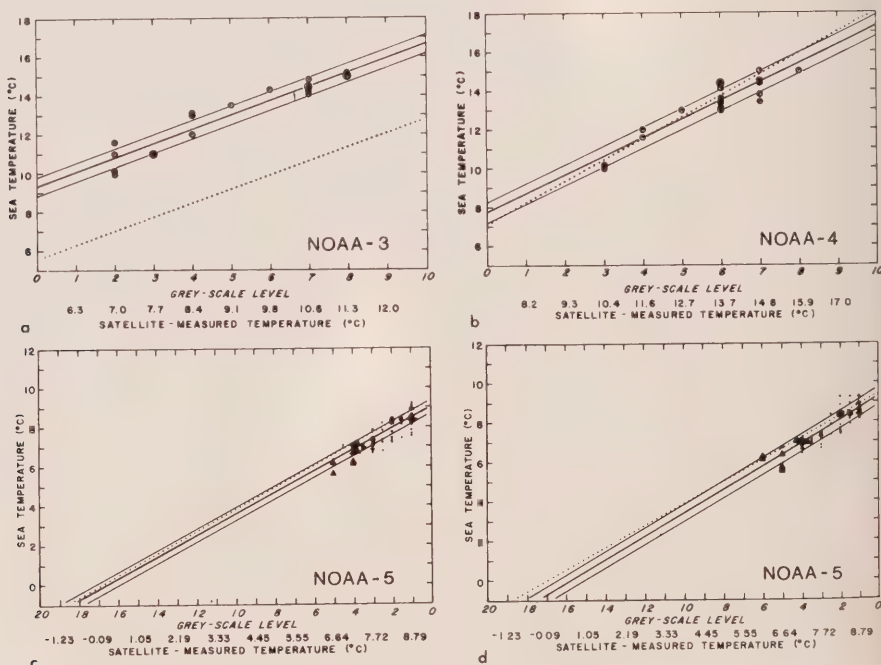
The high levels during 1963 and 1965-67, and the low levels during 1961 and 1968-71, are due mainly to the presence of low and high salinity, respectively. On the other hand, the higher levels during 1959-60 and 1974-75 resulted from the presence of warm water there.

dilution of seawater during autumn-winter and with salinity increases due to upwelling in the summer. Since annual warming and cooling occurs mainly in the upper 100 m, much of the annual range (6.0 cm) of the steric level is due to changes in that segment of the water column. At Station P, 90% of the changes relative to the 1,000 m depth occur in the top 100 m.

Whereas the annual cycle of the steric sea level in the open ocean is controlled by temperature effects, year-to-year changes are affected by both temperature and salinity, the latter having greater effect. For example, at Station P the higher steric levels during 1959-60 and 1974-75 are due to thermal effects, but those during 1963 and 1965-67 are saline effects. (*Contact: S. Tabata.*)

Accuracy of Satellite-Observed Sea-Surface Temperatures

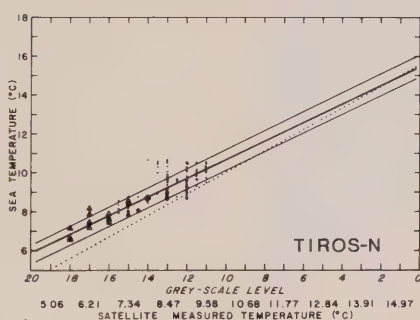
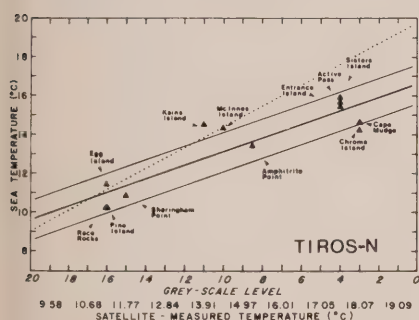
A comparison between ship-borne observations and sea-surface temperatures measured by satellites (NOAA-3, NOAA-4, NOAA-5, NOAA-6 and TIROS-N) off the Pacific coast of Canada indicates that, in each case, a linear regression is sufficient to relate the two sets of data. The standard errors for estimated temperatures observed by the above satellites were: $\pm 0.5^{\circ}\text{C}$, $\pm 0.6^{\circ}\text{C}$, $\pm 0.3^{\circ}\text{C}$ to $\pm 0.4^{\circ}\text{C}$, $\pm 0.6^{\circ}\text{C}$, and $\pm 0.5^{\circ}\text{C}$, respectively. These results suggest that, when reliable field calibration data (ground truth) are available, sea-surface temperature in a limited region and time can be measured accurately by the satellites.



Estimates of errors as large as $\pm 2^{\circ}\text{C}$ reported in the literature are suspected to stem mainly from errors in ship-borne measurements, failure to correct adequately for atmospheric effects, and uncertainty in the radiometer calibration. Since these problems have not been entirely solved, at present the method of applying field-calibration using good ground truth appears to be the only practical way of obtaining reliable estimates of sea-surface temperatures from satellite observations. (Contact: S. Tabata).

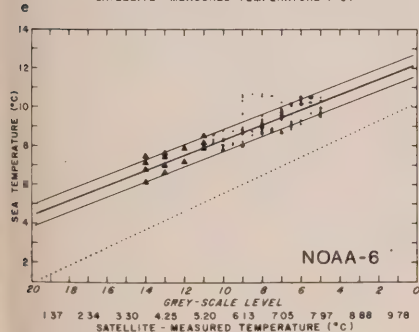
Inventory of Physical Oceanographic Information

A review of published and unpublished oceanographic data taken during 1906-1979 from Queen Charlotte Sound, Hecate Strait, Dixon Entrance and contiguous waters has been conducted, and the source, quality and availability of these data indicated. Included are: daily observations of sea-surface temperatures and salinities from coastal stations; hydrographic, CTD and BT casts, tidal heights, current velocity and wave measurements; and temperature data from thermistor chains. This review was made in response to the increased demand for marine environmental information prompted by interest in offshore petroleum exploration, the threat of pollution from potential oil tanker traffic, the search for little-exploited renewable marine resources, and potential sites for electric power generation from ocean waves and wind energy. (Contact: S. Tabata.)



Relationship between shipborne-shore station and satellite-determined sea-surface temperatures.

Because of atmospheric attenuation, satellite data should give temperatures a few degrees lower than actual temperatures. This would mean that only the NOAA-3 and NOAA-6 sensor calibration data can be considered reliable. There appear to be some calibration problems with the other satellite sensors.



The two lines about the heavier regression line represent the standard error of estimate.

The dotted line would represent perfect agreement between the oceanographic and satellite data.

c, d, f, and g: Triangles denote shore-station data that were collected within 12 hours of the satellite overpass but were not utilized to obtain the regression line.

Storm Response and Transfer Experiment (STREX)

A joint Canada-United States storm response experiment was staged during October-December in the vicinity of Station P (50°N, 145°W) in order to assess the evolution of the upper ocean and the atmospheric boundary layer during a period of high heat transfer from the ocean to the atmosphere. Current profiler and CTD surveys were conducted during two 14-day cruises of CSS *Parizeau*, simultaneous with surveys aboard the weather ship *Vancouver*. Experience gained during FGGE (the First GARP Global Experiment) was used to monitor and manage data received from the drifting buoy array which was also deployed in the area.
(Contact: M. Miyake.)



CTD survey on board weather ship
Vancouver.

AXBT Survey of North Pacific

The AXBT data set collected between 1976-78 during the NORPAX Anomaly Dynamics Experiment (ADS) is in the final phase of data analysis. Latitudinal variations in the physical mechanisms involved in the upper ocean structure have been identified. Locally-induced advection below the mixed layer at depths between 75-110 m in the vicinity of 48° in mid-ocean has been found to play an important role in determining both sea-surface temperature and year-to-year temperature variations through mixing from the surface. The advection velocity (in the order of 0.5 cm/s) can be determined not only from the stress vector, but also from the stress curl vector. These mechanisms can be determined diagnostically from the existing data set. (*Contact: M. Miyake.*)

Numerical Modelling

Institute of Ocean Sciences numerical modelling activities involve the development of numerical methods suitable for the planning and analysis of field observations. Models are also being developed for the prediction of pollutant transport, storm surges, ice movement, tidal flushing, current regimes, etc. These studies are useful in establishing design criteria for industrial marine developments, navigation, and recreation activities; they usually entail a minimal increase in field work.

A numerical model of internal hydraulic jumps using the triple-deck approximation was applied to Knight Inlet and Babine Lake. Preliminary work started in 1979 on tide-generated residual circulation was extended to include the role of stratification and non-linearities. Considerable progress was also made in a study of the interaction between tides and storm surges.

Collaboration with NOAA and the University of Hawaii continued on tsunami-related problems. A paper on a newly devised tsunami magnitude scale was published. At the invitation of the World Data Center-A in Boulder, Colorado, global tsunami data were examined, and recommendations made for statistical analysis and preparation of useful products. (*Contact: T.S. Murty.*)

A major project— to develop tidal and storm surge models for the Bay of Bengal— was initiated in 1980 at the request of the World Meteorological Organization and the United Nations Development Program. The aim was to produce a surge prediction model for operational use by the Bangladesh Meteorological Department. Visits were made to Bangladesh and archives in the United Kingdom to assess the availability of relevant tidal and hydrographic data for inclusion in the numerical models. (*Contacts: T.S. Murty and R.F. Henry.*)

An explicit finite difference method was developed; it uses minimum memory storage and computing time for any given tide or storm surge problem. A software package which permits semi-automated set-up of shallow water models was also developed. Work is proceeding on extending this package to cover non-linear effects, especially advection. The aim is to substantially reduce the time and programming effort needed to produce tidal, tsunami and storm surge models.

(Contact: R. F. Henry)

Extensive analyses of model results from earlier tidal studies (GF2 and GF3) have been completed by a private consulting company under contract. These will provide the bases for publications on barotropic tides and associated residual circulation within the Georgia/Fuca system. A tidal current atlas for this system is currently being prepared at IOS. The atlas will contain vector diagrams depicting tidal currents at hourly intervals for representative tidal ranges.

In 1980 numerical studies of the Georgia/Fuca system were predominantly concerned with pilot experiments. These sought a viable algorithm for applying the elevation and velocity fields obtained from an initial homogeneous fluid calculation simulating barotropic tides, themselves assumed to be unaffected by the internal density driven circulation. The algorithm would permit these elevation and velocity fields to be entered at each time-step into full baroclinic calculations of the estuarine circulation. Essentially, the method employs a "prescribed lid", permitting the employment of time-steps longer than those required for a full free-surface calculation. This may be regarded as similar to the adaptation for a strongly tidal deep coastal sea of the "rigid lid", a technique often employed to reduce the costs of ocean models. Such an algorithm has been developed and tested satisfactorily for the coast of a two-dimensional rectangular basin.

The dynamic validity of employing a "prescribed lid" to important events in the Georgia/Fuca system could be shown by comparison with full free-surface calculations in the simulation of deep water renewal. These would employ a simple variable width and depth laterally integrated numerical model (GF5) of the main conveying channels, i.e. Georgia Strait, Juan de Fuca Strait and Haro Strait. A number of sensitivity trials (varying the horizontal and vertical eddy diffusivities and viscosities, bottom and side friction) have been made using the free-surface mode of calculation to simulate deep water renewal during July, 1968. Though necessarily crude in these early stages of work, comparisons of computed and observed salinities are very encouraging.

Through the collaboration of Dr. Jan Backhaus of the University of Hamburg, the code for a seven-level, three-dimensional numerical model (GF6) based on the earlier four km-mesh-grid scheme (GF2) was completed. Six days of mixed tides (M_2+K_1) were successfully simulated in two trial computations using a homogeneous fluid and an initial salt distribution conforming to that of early July, 1968. (Contact: P.B. Crean.)

An assessment of oceanographic conditions during the loss of the bulk ore carrier, *Lee Wang Zin*, in Dixon Entrance on December 25, 1979, was carried out. This included analyses of wind-generated surface drift, tidal currents, sea state and drag on the vessel. A report has been submitted to the Canadian Coast Guard for inclusion in the final accident report. (Contacts: P.B. Crean and W.S. Huggett.)

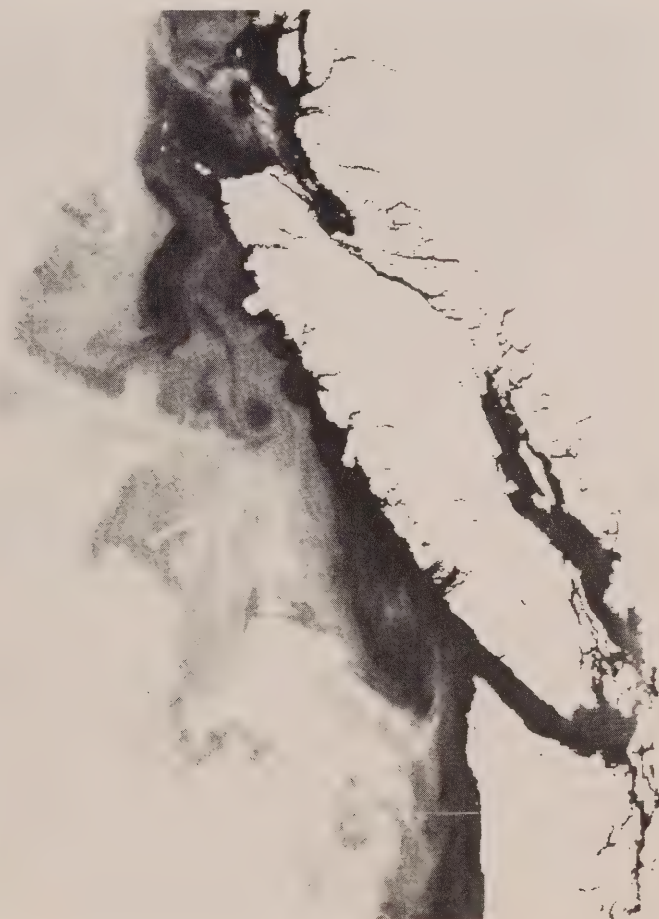
Remote Sensing

The Remote Sensing Section is responsible for developing aircraft and satellite remote sensing techniques to be used in oceanography, and for evaluation of techniques originating elsewhere.

The effect of phytoplankton chlorophyll absorption shows strongly in this band 1 (blue) Coastal Zone Colour Scanner image of the waters off Vancouver Island, B.C., Canada, on July 14, 1979.

Cloud and land areas appear white. Increasing absorption of blue light by chlorophyll causes biologically more productive waters near the coast to appear dark.

Radiance values measured by this scanner can be related to chlorophyll concentration, and the spatial patterns can be interpreted in terms of water circulation.



Water colour research for surface chlorophyll mapping in the world's oceans and coastal seas is receiving a strong boost from data at last available from the Nimbus 7 satellite's coastal zone color scanner. Images off Canada's west coast, while infrequent because of cloud cover, can show those patches of water, coloured by their higher chlorophyll content, where enhanced plankton growth is occurring. Mapping of this "primary" productivity is important in understanding the ecology of fish.

The remote sensing group has participated in air and ship measurements of surface chlorophyll concentration off the west coast of Vancouver Island since 1978. In 1980 the work involved a ship-of-opportunity program organized by Seakem Oceanography Ltd.

The use of water colour variations to trace water motion was demonstrated; an image of a plankton bloom occurring south of Iceland was used to calculate the spatial frequency spectrum of two-dimensional meso-scale turbulence. Although this spectrum is difficult to measure using ships or aircraft, it has considerable significance in geophysical fluid mechanics.

Research aimed at improving chlorophyll surveys by making use of the fluorescent line at 685 nanometres led to a series of 1980 flights to test the feasibility of mapping the fluorescence signal from high altitudes or from space. An evaluation of this possibility is now being carried out by the Canadian Corporation for University Space Science, CCUSS, with participation by British Columbia, Calgary and York universities, along with Moniteq Ltd. and Itres Research Ltd.

Analysis of data from the microwave instruments on SEASAT is continuing and the precision, detail and 'tuning' of algorithms are being improved. Digital processing of radar images gives much improved resolution. Satellite sensors now appear capable of yielding global wind and wave data superior in many ways to that obtained by traditional surface sources.

The proceedings of the international colloquium on "Passive Radiometry of the Ocean" appeared in early 1980 as Volume 18 of Boundary Layer Meteorology. These papers demonstrated the types of measurements that would be expected from space when suitable satellites were launched. A more comprehensive symposium on "Oceanography from Space" was held in May, 1980, in Venice, Italy. The proceedings demonstrate the accuracy and coverage capabilities of SEASAT and NIMBUS 7 satellite-mounted instruments.

Other projects include: development of radar tracking and radio location for drifting buoys; adaptation of a Loran-C receiver for use in an aircraft; and evaluation of options for an improved image processing facility at IOS. (*Contact: J. Gower.*)

Computing Services

Just prior to the end of 1979, the Evaluation and Audit Branch of the Department of Fisheries and Oceans conducted an evaluation of the IOS Univac 1106 Computer Centre and concluded that, "the majority of users are well-satisfied with the service offered and cost of the in-house service is significantly lower than that of the best (external service) bureau option".

A subsequent internal study, conducted during March-September, specified an alternative for meeting long-term computing requirements at IOS. The recommended option was to upgrade the 1106 to a new Univac 1100/60 configuration; this would produce a substantial cost saving. Treasury Board approval to proceed with the upgrade was imminent at year's end.

Univac staff continued to be engaged in user support, operating system maintenance, preparation of news releases describing the operating system, language compilers, system libraries, and application software. The Numerical Algorithms Group (NAG) library of mathematical routines was acquired. Development of the new plotting system featuring a large on-line Houston drum plotter was nearly completed. A collection of useful routines from the University of British Columbia Computing Centre was implemented on the Univac, and supporting documentation was produced. A Univac 1106 Users' Manual was published to augment existing user documentation.

System utilization increased 36% from an average monthly value of approximately \$41,000 in 1979 to over \$56,000 in 1980. (*Contact: K. Teng.*)

Automated Cartography

In 1980 the first chart (7686, for the Arctic) using the Automated Cartography system was completed. Most of the information on the chart was digitized, registered, windowed, symbolized, plotted, checked, edited, and finally broken down into overlays and plotted on photographic film. It will be printed early in the new year. The system is being used for selected additional charts, but because the accuracy of the digitizing table is not quite adequate for chart construction, a more accurate table has been ordered.

No hardware changes were made to the system in 1980, but the software was modified extensively. A new Fortran-IV PLUS compiler was obtained, and all existing software converted to it. Symbolization software and a variety of utility programs for manipulating interchange graphics files from Ottawa were added. Many programs were modified to correct

bugs in chart digitization, or to handle features which are different from those being used in headquarters.

As a result of a reorganization of Computing Services, there are now four functional areas: Numerical Modelling; Ocean Physics and Minicomputers; Hydrography and Computer Graphics; and Computing Centre and other.

The IOS Financial Accounting and Reporting System (FARS) was converted to the Univac system. This facilitated the development of an interface with the departmental Financial Allotment Control System (FACS), which runs on an external service bureau. To eliminate duplicate data entry, the Univac FARS system generates input transactions for FACS during FARS update runs.

Ocean Chemistry

The Ocean Chemistry Division provides expertise and advice on the chemical aspects of the marine environment, by conducting research and monitoring at the regional, national and international levels. These activities contribute to policy, legislation and scientific knowledge.

At present, two of many potential marine chemical problems seem most urgent. One is the assimilative capacity of the ocean for industrial wastes. The other is the ocean's capacity to absorb atmospheric carbon dioxide (CO₂) generated by the burning of fossil fuels. The marine waters along our coastlines receive thousands of new chemicals that are discarded by industries, cities and natural river drainage systems. New activities such as oil drilling, mining and forest logging pose additional stresses. It is necessary to review and improve our understanding of these factors for both natural and man-made substances, so that legislation designed to safeguard the marine environment will be based on the best current evidence.

The second concern, assimilation of CO₂, is related mainly to climate. The global carbon cycle is extremely complex and difficult to quantify. However, the trend toward an increase in atmospheric carbon dioxide is clear. It has the potential to cause a general warming effect, moderated by the ocean's capacity to both absorb and produce CO₂. The recently established Marine Carbon Research Centre at IOS provides a focus for research into the marine carbon cycle. Its interests include sources, sinks and pathways of CO₂, and modelling efforts leading to predictions of future trends. Enclosed ocean experiments, weathership CO₂ monitoring, and research cruises (including that planned for the *Hudson* in 1981) are

used to check the validity of assumptions and to increase knowledge of this cycle.

A wide range of chemical programs was undertaken this year. To date, the basic open ocean effort has been the weathership program. Having celebrated the tenth anniversary of CO₂ time-series at Station P last year, a shift to other platforms was made in order to minimize the impact of the weathership phase-out in 1981; the new platforms include lighthouses, ships-of-opportunity and the research vessel, *Parizeau*.

Efforts to understand chemical processes and interactions between phytoplankton and the chemistry of sea water were pursued through an international SEAFLEXES program, which evolved from CEPEX work. An international symposium on Marine Controlled Ecosystem Experiments was hosted, and SEAFLEXES studies were conducted jointly with the Kiel Institut für Meereskunde, the Institute of Biological Sciences at the University of Tsukuba in Japan, the Department of Oceanography at the University of British Columbia, and the Quebec Region of Ocean Science and Surveys. Coastal studies included key environmental problems such as mine tailings disposal, ocean dumping contract research, environmental contaminants contract research, and a Kitimat chemical study.

Very fruitful interaction took place with a large number of scientists visiting for extended periods at IOS. They included: Dr. Goldberg from Scripps Institute of Oceanography and Dr. Bertine of San Diego State University, both on sabbaticals; Dr. Ostlund from the University of Miami; Dr. Klaus Kremling, Dr. Smetacek and their associates from the Institut für Meereskunde at Kiel; doctors Ichimura, Seki and Takahashi from the University of Tsukuba; Dr. Handa from the University of Nagoya; Dr. Parsons and Dr. Lallo from the University of British Columbia; Dr. Lu Xiankuan from the Institute of Oceanography at Shandong University; and Dr. and Mrs. Cosson from the Oceanology Center of Brittany. A delegation from China headed by Dr. Li Guan-guo visited for preliminary discussions on scientific co-operation and future training of marine scientists.

Marine Carbon Research Centre

The carbon cycle is one of the major keys to understanding chemical processes and transports in the ocean. The role of CO₂ has, in recent years, evolved into a significant global issue because of its potential climatic effects. The OSS Marine Carbon Research Centre at IOS, now in its second year, is focusing on marine aspects of carbon dioxide's climatic effects.

Carbon dioxide is taken up by land plants and marine phytoplankton through photosynthesis, and released by respiration and decay. Such processes are very large and variable. Monitoring the secular increase, a minute fraction compared to the biota fluxes, requires the use of high-

precision measurements over the complete seasonal cycle every year, and maintenance of CO₂ standards on a long-term basis. One of the main IOS activities has been to conduct time-series CO₂ studies over the Pacific Ocean. However, Ocean Weather Station Papa (50°N, 145°W) is now expected to be phased out. To partially compensate for this loss, lighthouse stations at Amphitrite Point, Kains Island, and at Cape St. James, as well as a ship-of-opportunity, the *Canada Maru* sailing between Tokyo and Vancouver, have all been equipped with instruments. The CSS *Parizeau* initiated research vessel cruises in August as part of the weathership replacement program.



Sites of Canadian CO₂ stations.

There is evidence to suggest that atmospheric CO₂ at Ocean Weather Station P is affected by oceanographic events several thousand km distant, such as the El Nino phenomenon off Peru. Apparently this results from the decreased supply of CO₂ to the ocean surface, and diminished upwelling of deeper waters at times of decreasing offshore winds.

There is also an effect attributable to anomalous surface temperatures further upstream, near northern Japan. These were discovered in joint work with Scripps Institution of Oceanography, the Geophysical Monitoring of Climatic Change group, and NORPAX scientists. Inter-relationships such as these demonstrate that the action of the surface mixed layer on marine air is a large-scale global phenomenon, and that international co-operation will be necessary in order to understand it fully.

The dynamics of CO₂ in the surface mixed layer are far more complex than those of marine air CO₂. Oceanic CO₂ is more intimately linked with marine phytoplankton, which act as an efficient CO₂ pump. Based on the earlier discovery of high seasonal particulate carbon fluxes at Ocean Weather Station P, a long-term flux monitoring program is being established. The first stage involves instrument development for a Neutral Buoyant Sediment Trap (NBST). The second project, MASTS (Moored Arrays of Sediment Trap Systems), uses moored traps and samplers installed on Line P. The project is at the instrument preparation stage, and is scheduled for launching in August, 1981. To understand the effects of storm and wind-stirring on oceanic CO₂, both seawater and atmospheric CO₂ were measured at the ocean surface during the STREX observational period. (*Contact: C.S. Wong.*)

Hydrocarbons and Pesticides

Petroleum-based compounds— organics, PCBs, PCPs and pesticides—are entering the marine environment with increasing variety and quantity. Their toxicity and general behaviour in sea water are poorly understood. The need for more and better information about these contaminants is clear.

The emphasis at IOS has been placed on the marine environmental significance of two organic pollutants: pentachlorophenol (PCP), a common fungicide and wood preservative; and polycyclic aromatic hydrocarbons (PAHs). The work was supported by the Environmental Contaminants Contract Fund from the Environmental Protection Service. PCB was found to inhibit bacteria growth at a concentration of $\mu\text{g/l}$ in the laboratory study, but it affected phytoplankton only marginally in an enclosed ocean field experiment. (*Contacts: W. Cretney and C.S. Wong.*)

The distributions of the polycyclic aromatic hydrocarbons (PAHs) and aliphatic/alicyclic hydrocarbons were investigated in Kitimat fjord sediments

using the instrumental techniques of capillary gas chromatograph-mass spectrometer data system (GC²/MS/DS). Natural sedimentary material could be distinguished qualitatively from present-day Kitimat harbour material. The contemporary sedimentary hydrocarbons are similar to those produced in aluminium smelter plants employing vertical Soderberg electrodes, such as those of the Alcan smelter in Kitimat. In particular, the long chain hydrocarbon n-alkanes in Kitimat harbour differed greatly from background marine sediments for the area. (*Contacts: W. Cretney, R. Macdonald and C.S. Wong.*)

Participation in the Baffin Island Oil Spill (BIOS) project included serving as scientific authority and Chairman of the Chemical Subcommittee on the chemical fate and effects study. The objective of the project is to compare the impact of undispersed and chemically-dispersed crude oil in Arctic coastal ecosystems. Preliminary study has shown the experimental sites chosen for controlled oil spills next summer to be almost pristine, with the dominant hydrocarbons biogenic in origin. Some petrogenic and combustion-derived hydrocarbons, indicative of long-range transport, were detected; but their occurrence was both extremely low, and distinguishable from the crude oil used. (*Contact: W. Cretney.*)

Attention was also given to more local problems, most particularly a proposal to move an oil tank farm from Victoria to Hatch Point on Saanich Inlet, not far from the Institute. A baseline survey is being conducted for the marine waters and sediments near the proposed site and in Victoria harbour, so that chemical and ecological studies can provide a comparison between the two areas. (*Contact: W. Cretney.*)

Enclosed Ocean Experiments

Enclosed ocean experiments have evolved into a significant tool in marine research. They are defined as medium-scale enclosures of sea water and plankton (60,000-1,000,000 litres range) capable of sustaining an ecosystem for experimental purposes. This "simulated world" is strategically placed between the "artificial world" of laboratory bottles incapable of supporting a representative biological community, and the "real world" of the open ocean with its complex interactions. Enclosed ocean experiments are an effective compromise for research into pathways, budgets and processes of pollutants and natural compounds in the marine environment.

An international SEAFLEXES program has been initiated, following the transfer of previous CEPEX facilities from the U.S. National Science Foundation. Co-operative international research was conducted during the summer. (*Contact: C.S. Wong.*)

An enclosed ocean experiment to study manganese/copper interactions

with sea water and copper-dissolved organic formation was undertaken, in co-operation with the Department of Chemistry at the Institut für Meereskunde, Kiel University. Approximately 5% of a $2\text{ }\mu\text{g/l}$ copper spike became associated with the dissolved organics. Thermodynamically, oxide $\text{Mn}^{(\text{IV})}\text{O}_2$ is insoluble and stable in oxygenated sea water. However, soluble divalent $\text{Mn}^{(\text{II})}$ is found in high concentrations in estuaries and deep waters. Initial results for manganese indicated $\text{Mn}^{(\text{II})}$ failed to precipitate for over a week after the addition of artificially precipitated MnO_2 , while addition of MnO_2 crystals led to faster $\text{Mn}^{(\text{II})}$ removal within 24 hours. (Contacts: K. Kremling and C.S. Wong.)



The CHEMCELL sediment/sea water experimental system in Saanich Inlet, B.C. It was used in the international SEAFLEXES program, hosted by the Ocean Chemistry Division.

The third experiment involved study of the carbon budget and pathways, especially the heterotrophic utilization of glucose-C, using a ^{14}C labelled tracer. The Institute of Biological Sciences at Tsukuba University, the University of British Columbia and Kiel University all participated in the use of the new CHEMCELL system attached to the sea floor. Uptake kinetics and turnover time of dissolved organics (amino acids, carbohydrates, and organic acids) were investigated. Monitoring of the new sediment/sea water enclosure's performance continued into the fall, during which time a short experiment comparing various productivity measuring techniques was also conducted. (*Contacts: Wong, Seki, Takahashi, Handa, Uchimura, Parsons, Lallo and Smetacek.*)

Coastal Pollution

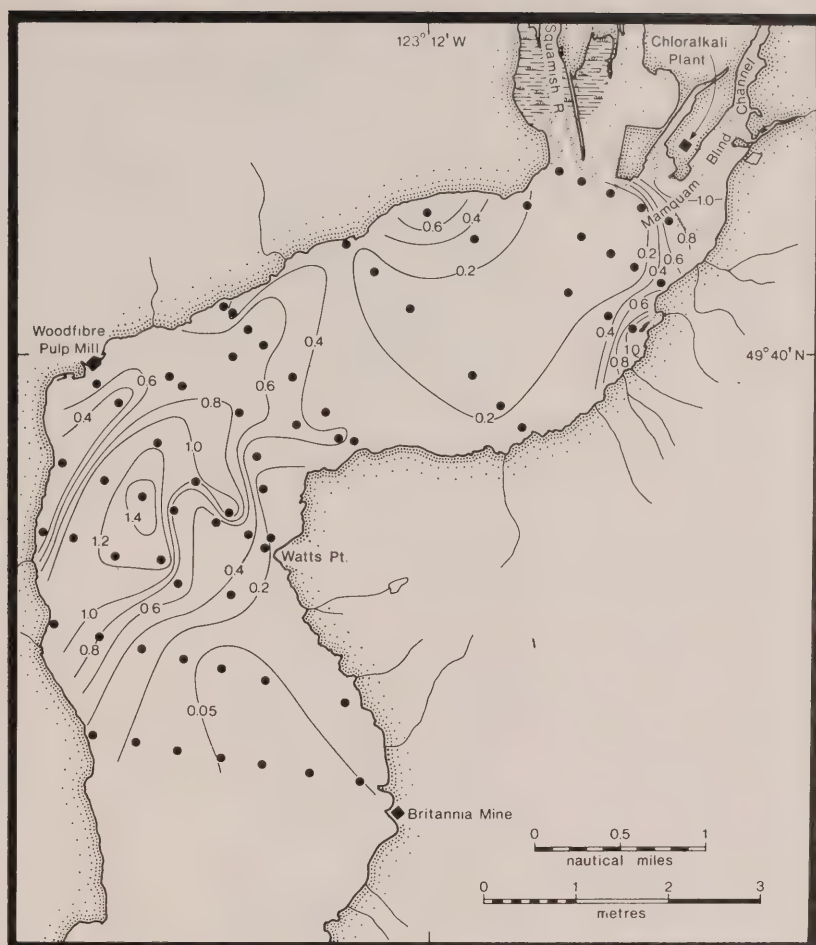
Mining is one of the major industries in British Columbia, and marine mine tailings disposal is causing increasing environmental concern. In response to that concern, IOS is gathering information on baseline levels and trends of heavy metals in marine organisms, with a view toward determining the processes by which these metals are converted to toxic forms, and toward learning more about de-toxification mechanisms operating within marine organisms.

Investigations of mine tailings discharge concentrated on Alice Arm in northwestern British Columbia, the site of the AMAX molybdenum mine at Kitsault which is expected to be reactivated. During two cruises, pore water samples and sediment cores for metals (lead, copper, cadmium, manganese) and other chemical parameters (sulfide, nutrients, Eh) were collected. The data obtained thus far do not suggest a marked difference between metal concentrations in the pore waters originating from previous tailing deposits and those found in the natural sediments. (*Contact: J. Thompson.*)

Metallothionein studies were initiated this year to determine if the concentration of this metal binding protein varies with the proximity of an organism to a polluting source. Laboratory work in progress is investigating the protein in oysters collected from beach areas near Crofton, where large quantities of zinc have been discharged in recent years. (*Contacts: Thompson, Cosson.*)

Analytical methodology was developed under contract for the quantification and speciation of tin and its organic derivatives in various environmental fluids (i.e., fresh and salt water, sewage) using gas chromatography/mass spectrometry. Lead^(II) compounds were also studied under anoxic conditions; results indicate that methylation occurs only in small quantities, exhibiting no increased production with time. These methylation studies help in understanding possible bio-transformation of these metals and their potential for subsequent mobilization into overlying waters. (*Contact: Thompson.*)

Mercury distribution in marine sediments of Howe Sound, B.C. The area has several possible point sources of mercury contamination, and is environmentally sensitive because of conflicting interests of industry and the public.



Arctic and Fjord Chemistry

Considerable effort was directed toward clearing up a backlog of environmental data to meet increasing demands from oil companies, government agencies and the public. Priority was placed on arranging a Kitimat workshop to disseminate that data, and to formulate future multi-disciplinary research and monitoring needs for this environmentally sensitive fjord system on the northern B.C. coast.

In Howe Sound, marine sediment was collected for ocean dumping research. Post-dumping migration of mercury from contaminated sediments was investigated by radio tracer. Oxidic, near anoxic and sulphidic

conditions were examined to determine the most appropriate dumping strategy. Mercury does not appear to migrate under these conditions, but does appear to become tied up with the organic and sulphidic phases. On the other hand, cadmium was released back into the water column when the sediments went from anoxic to oxic conditions. Previous data from Port Alberni were also examined to determine the influence of ocean dumping practices on particulate and dissolved organic carbon, and the use of the carbon/nitrogen ratio as a measure of the organic matter supply. (Contact: R. Macdonald, C.S. Wong.)

Ongoing Arctic research was pursued by contract. Cadmium in Churchill harbour sediments was examined, following a rather difficult sampling program that was hampered by ice conditions. Sea water and sediment samples were analysed for cadmium, zinc, copper, mercury and lead. The metal levels detected were not significantly different from those of natural sediment elsewhere. High values, in excess of acceptable limits for dumping, previously reported by another laboratory, may have resulted from analytical problems. (Contact: R. Macdonald.)

A Beaufort Sea chemical data report summarizing all the shipboard nutrient and other chemical data taken in 1974 and 1975 was completed. (Contact: C.S. Wong and R. Macdonald.)

Weathership Program

The study of long-term trends of chemical parameters at Ocean Weather Station PAPA (50°N, 145°W) continued in 1980. Part of this effort was diverted toward establishing a replacement program in anticipation of the weatherships' phase out in 1981. Neuston net tows were made between Victoria and Station P to collect tarballs and other surface pollutants. Weekly samples of atmospheric CO₂, surface alkalinity, total CO₂ and surface radiocarbon were taken, together with some continuous shipboard infra-red measurements of marine air CO₂ and pCO₂ on the CSS *Quadra*. Nutrient samples were taken to provide information about long-term fluctuations and their relationship to circulation and the marine food chains. Particulate detritus organic carbon and chlorophyll-a were also collected. (Contact: C.S. Wong.)

Trace Metals in Sea Water

The major objective of the trace metal program is to assess natural and man-made additions of physiologically significant metals to the ocean, especially their interactions with suspended matter, the planktonic biota and surface sediments.

NATO funding was received to assess the gap in knowledge between state-of-the-art laboratory detection of trace metal levels and those currently being employed for modelling of chemical speciation and

biological effects. The development of "standard sea water" with trace metal concentrations near natural levels is the object of continuing long-term research. This research involves accurate measurements of trace metals with ultra-clean laboratory techniques, coupled with mass spectrometry and other instrumentation.

A long-term storage study of lead, mercury, cadmium, zinc, copper, nickel, cobalt and iron in sea water was completed; it indicated the feasibility, for most metals, of storing sea water over a period of at least 230 days under carefully controlled conditions. Through co-operation with Dr. C.C. Patterson's group at California Institute of Technology, a contaminant-free sampler was constructed after the Cal Tech design, and an inter-calibration conducted during the August cruise of the CSS *Parizeau* in the northeast Pacific. A further objective of the work is to understand and model the flux of metals between, and accumulation of, metals within the important environmental components: sea water, marine biota and surface sediment. This is being addressed through a five-year SEAFLEXES program (sediment/ecosystem/atmosphere flux enclosure study) of enclosed ocean experiments. (Contact: C.S. Wong.)

Sampling for trace metals in sea water during an inter-calibration cruise with California Institute of Technology, using the Schaule-Patterson contaminant-free sampler.



Total mercury time-series measurements in Saanich Inlet included profiles at the surface, where waters are representative of an oxygenated environment, and at depth, where conditions are anoxic. A marked change was evident at the surface. Measurements were also taken during a recent period of deep-water renewal resulting from tidal flushing. This is a co-operative project with the Institute of Oceanography at Shandong

University, Qingdao, People's Republic of China.
(*Contacts: Wong, Lu and Macdonald.*)

Tin and antimony in Saanich Inlet were also studied. Water column samples were taken with particular emphasis on the oxic-anoxic boundary. Interstitial water samples were taken in several different inlets, including some in more oxygenated sediments at about 75 m depths, using an *in situ* sea water sampler. (*Contacts: Bertine, Wong, Thompson and Barnes.*)

Ocean Ecology

Ocean Ecology at the Institute is directed mainly toward understanding two phenomena: the impact of ocean climate on the distribution and productivity of phytoplankton, which are the basis of the ocean's food web; and the reaction of benthic communities to natural and man-made stresses.

Plankton

The second full year of studying biological processes off the west coast of Vancouver Island was completed. Very high standing stocks of plankton were again observed. Also established were details of the summer movement of upwelled water carrying high dissolved nutrient load and low oxygen concentrations. The pathway for this infusion of nutrient-rich water onto the shelf appears to be along a tributary of the Juan de Fuca submarine canyon. Results from the shelf program began to appear in formal publications, and have also been presented at conferences. (*Contacts: K. Denman and D. Mackas.*)

Studies of zooplankton aggregations at salinity fronts in the Strait of Georgia were continued. Previous observations of surface aggregation were confirmed and refined, and new observations of vertical distribution near the salinity front were initiated. (*Contact: D. Mackas.*)

Other new work included the investigation of effects of fluctuating light and turbulence on phytoplankton photosynthetic production. Submarine light decreases rapidly with depth, but vertical cycling of phytoplankton by turbulent eddies effectively increases the range of exposure to light. We have been estimating time and space scales for vertical cycling of phytoplankton that are subject to different wind-forcing and density stratification, by using recent turbulent microstructure results. Initially, we find that the estimates are extremely sensitive when the stratification is weak, as in the upper ocean above the seasonal thermocline during summer months. Another study will be a laboratory experiment in which continuous cultures of phytoplankton will be subjected to light varying by intensity and frequency. (*Contacts: K. Denman and A. Gargett.*)

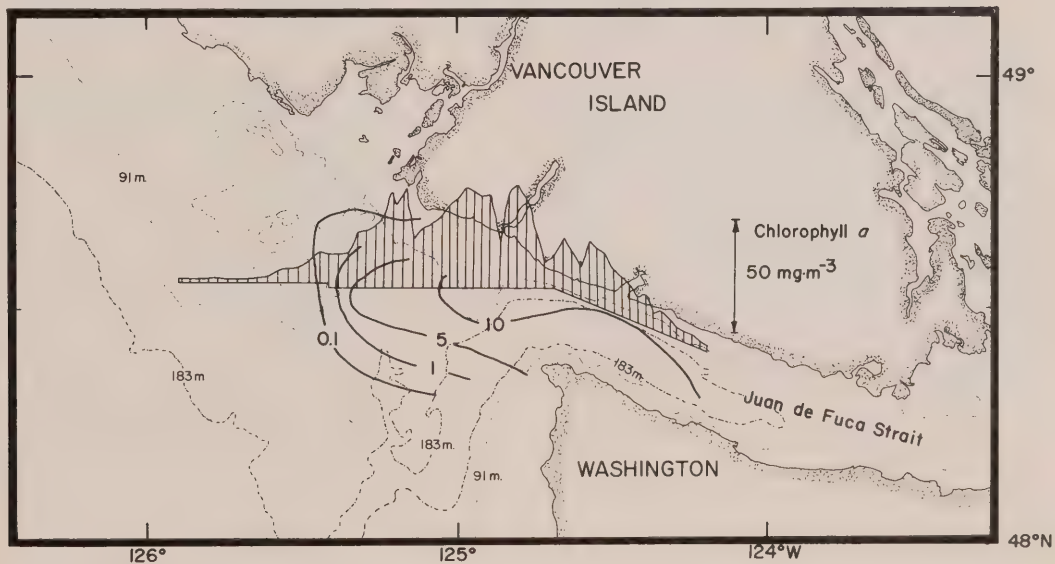
An analysis of phytoplankton patchiness as observed from a Landsat satellite was completed. From the variance by patch size, it was concluded that the growth rate of phytoplankton is not sufficient to affect the patchiness; rather, it is controlled by the large-scale oceanic eddy structure. (Contacts: K. Denman and J. Gower.)

Several modifications were made to the electronics of the vertical profiler to improve power efficiency, accuracy and reliability, and to reduce electrical noise. In addition, a complete processing system for data from the vertical profiler was developed and tested on the IOS UNIVAC computer.

Further efforts have been made to enhance and extend our ability to measure ocean optical properties. The electronics of the MARTEK transmissometer were completely redesigned and replaced, in order to make the instrument compatible with the vertical profiling system. Electronic and mechanical interfaces were developed to mate a LICOR spherical quantum sensor measuring photosynthetically active irradiance with the vertical profiler. Together with a surface reference quantum sensor, this will allow measurement of temporal and spatial fluctuations in the photosynthetically active portion of the ocean's light field.

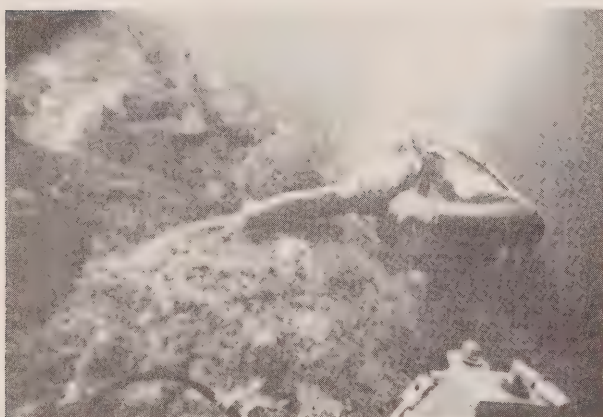
Also, an alternative amplifier package has been developed for the VARIOSENS fluorometer, giving true logarithmic response to fluorescence. This, together with newly-developed calibration procedures, should improve the accuracy and reliability of the instrument. (Contact: S. Hill.)

Spring bloom of phytoplankton near the mouth of Juan de Fuca Strait in May, 1979. Vertical bars represent chlorophyll pigment concentrations of near-surface phytoplankton, measured along a ship transect. Solid lines represent near-surface nitrate and nitrite concentrations from a grid of stations.

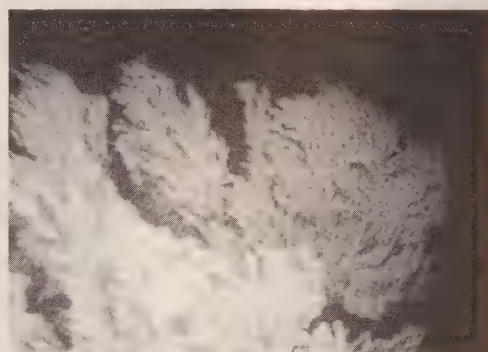


Benthos

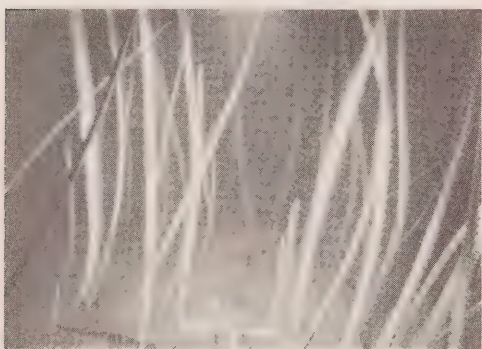
The benthic program began in earnest with the submarine exploration of Saanich Inlet and other fjords, using *Pisces IV*. The visual observations of the fauna attached to the walls are the first to be made in detail in any fjord. With the aid of photographs and collections from the submersible, the inhabitants of these "cliff communities" are being identified. We are monitoring the response of these animals to changing oxygen conditions, and conducting experiments to study recruitment and growth. Saanich, Jervis and Knight inlets are the targets of these studies, because of the variations in their sedimentation, dissolved oxygen and water turbulence. Study collaborators are from the University of Victoria, the University of Alberta, and the Pacific Geoscience Centre at IOS.



1. In Saanich Inlet, scuba diver (also *Pisces IV* pilot) meets the submersible at 15 m.



2. On the sill in Knight Inlet, workers in *Pisces IV* found extensive growths of a bright orange 'soft' coral. Despite the rapid currents, these corals grew to a height of over two m here at 70 m.



3. The inner sill of Howe Sound is covered with forests of seawhips, another type of coral, which were taller than the submersible. The scale is 30 x 30 cm.



4. The vertical walls of Jervis Inlet support the growth of a wide variety of animals, including this sea anemone at 400 m.

In August, studies of extensive damage caused by hurricane "Allen" to coral reefs on the north coast of Jamaica were conducted. This provided a unique opportunity to examine the reaction of a coral reef's diverse flora and fauna to such a massive disruption. (Contact: V. Tunnicliffe.)

A thesis study has begun on a very abundant squat lobster (*Munida*) that seems able to approach the de-oxygenated layer in Saanich Inlet, and migrates in response to seasonal changes in the extent of that layer. Some other crustaceans, notably amphipod shrimps, are also being investigated. (Contact: Burd.)

A study of the benthos of the continental shelf off the west coast of Vancouver Island is in the proposal stage; its purpose would be to investigate potential coupling of the benthos with observed plankton patterns.

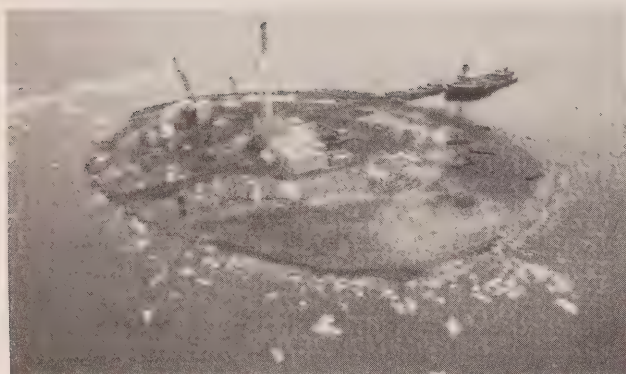
The oligochaete (sludge worm) study progresses. Training was provided for several government, industrial and academic scientists. A major reference work on European marine species was completed at the request of the Linnean Society of London, and a fresh water reference is being revised for the Freshwater Biological Association (Britain). The proceedings of the first International Conference on Aquatic Oligochaetes (Victoria, 1979) were edited and published. The study of lethal and sublethal responses of worms to a variety of contaminants under a wide range of experimental conditions is nearing a successful conclusion. A study of marine species will be completed in 1981, and several publications are in press, or have been published. Among them are guides to the marine worms of North America and to the *enchytraeidae*, a family in need of detailed revision. (Contacts: Baker, Brinkhurst and Coates.)

Planning has been started on future benthic projects in co-operation with European scientists from areas with fjord coastlines, and similar industrial and fisheries problems; a joint project is planned in Saanich Inlet for 1982. (Contact: R.O. Brinkhurst.)

Ocean dumping monitoring was carried out, and was transferred to the Ocean Information Division. (Contact: R.H. Herlinveaux.)

Ocean Information

The Institute of Ocean Sciences consolidated several existing activities and initiated new programs with the formation of the Ocean Information Division in August, 1980. The new division supports the management, protection and exploitation of marine resources— by gathering and disseminating oceanographic information and data, and by providing a marine environmental review service for the Canadian west coast and the western Arctic. This involves participating in the Environmental



*Beaufort Sea artificial island,
needed for year-round drilling
operation and production.*

Assessment and Review Process (EARP) and in numerous committees, including the Regional Ocean Dumping Advisory Committee (RODAC), the Arctic Waters Advisory Committee (AWAC) and the Department of Fisheries and Oceans Arctic Offshore Development Committee (ARCOD). Oceanographic information and advice is made available to the general public, as well as to scientific users. Marine environmental overviews and assessments serve as guides to regulatory agencies, industry and research planners. A media relations program is also under development.

By the end of 1980, substantial contributions had been made to the Federal Environmental Assessment and Review Office (FEARO), several AWAC, RODAC, ARCOD and joint government/industry meetings. The new division had also developed a strategy for responding to requirements for short-term environmental impact assessments and long-term research data in relation to industrial activities proposed for the Beaufort Sea and the western Arctic. Joint government/industry contract projects will compile, appraise and store Beaufort Sea physical and chemical oceanographic data. Also underway are several case studies to provide mass balance and flux estimates of both natural and industrial effects on the Beaufort Sea environment, with particular regard to the influences of dredging, oil spills and natural variability of physical and biological systems.

Another project to be conducted jointly with industry will compile and assess the quality of physical oceanographic data from the Sverdrup Basin and the Northwest Passage. This will assist the design of an extensive three-year oceanographic program now in the planning stage.

To consolidate available marine environmental information, the first phase of a major project was completed; it involved compiling technical records of existing Arctic environmental assessments, as well as reviews and data reports from industry, government and university sources. The second phase of this work will be a computer inventory during the summer of 1981; the inventory will include Pacific Ocean information, and will focus initially on B.C. coastal regions proposed for port development and offshore resource exploitation.



Ships



CSS Parizeau

The Pacific Region Ship Division provided ship, submersible, launch and depot support for the 1980 scientific programs of IOS, universities and other federal agencies.

CSS PARIZEAU (64.3 m overall; 1929 tonnes)

Master: A.G. Chamberlain *Chief Engineer:* P. Olcen

CSS *Parizeau* was employed in support of scientific programs involving the Institute's Hydrographic Division, Tides and Currents, Ocean Chemistry, Ocean Ecology, and Offshore Oceanography. The *Parizeau* also provided support for Loran-C calibration, the Pacific Geoscience Centre's geology program, the Department of National Defence's Ocean Acoustics section, and the University of British Columbia's Oceanography Department. In addition, the *Parizeau* spent six weeks as a primary S.A.R. (Search and Rescue) vessel for the herring roe fishing season.

CSS VECTOR (39.6 m; 505 tonnes)

Master: K. Sjöholm *Chief Engineer:* J. Orr-Hood

CSS *Vector* carried out duties in support of Institute programs in Coastal Zone Oceanography, Ocean Chemistry, Offshore Oceanography and Ocean Ecology. Other agencies assisted include: the Pacific Environmental Institute; the Environmental Protection Service; and the oceanographic departments of the University of British Columbia and Simon Fraser University.

CSS *Vector*



CSS RICHARDSON (19.8 m 78 tonnes)

Master: M.G. Wheeler Chief Engineer: A. Conway

CSS *Richardson* was used mainly for the Queen Charlotte Islands hydrographic survey, and as a primary search and rescue vessel during the herring roe fishing season.

MV PANDORA II, on charter (58.2 m; 1220 tonnes)

Master: R.A. Jones Chief Engineer: J. Newton

MV *Pandora II* carried out programs in support of: Simon Fraser University; the Environmental Protection Service; Ocean Chemistry and Offshore Oceanography. In conjunction with *Pisces IV*, *Pandora II* supported programs for Coastal Zone Oceanography and Tides and Currents. *Pandora II* also supported *Pisces IV* during trials for the modified 2000 m depth capability. In July, the vessel departed for the western Arctic in support of the Beaufort Sea hydrographic survey. An early ice pack around Point Barrow forced the vessel to leave the Arctic by the eastern route, and it is currently wintering in Halifax.

PISCES IV (6.1 m; 12 tonnes)

Chief Pilot: F. Chambers

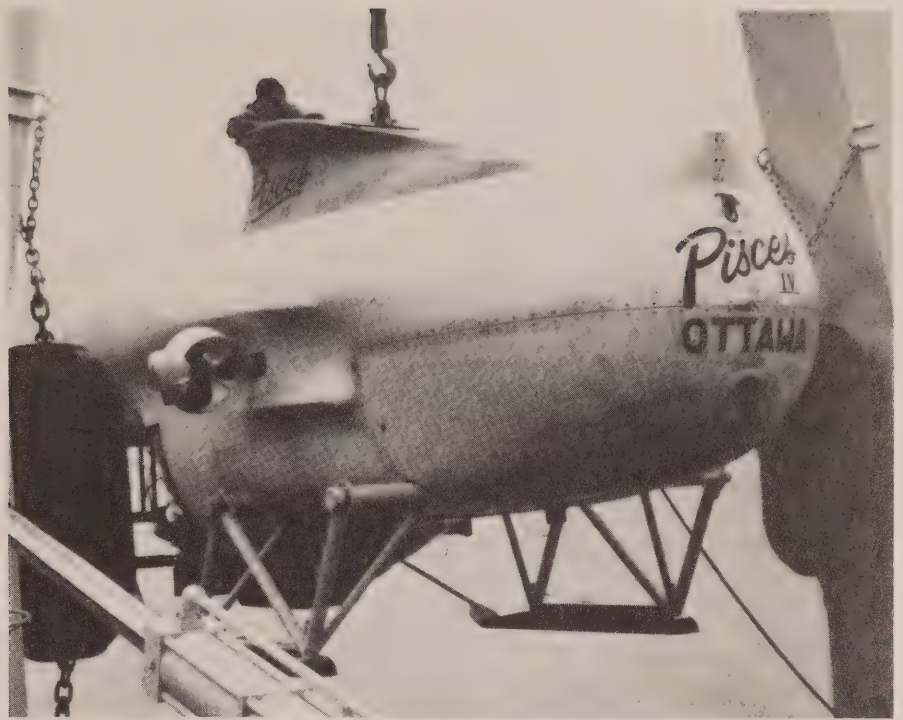
Pisces IV, our deep-dive submersible, was extensively modified and performed a test dive to 2000 m. Soon to be installed is a new tracking system which will enable this craft to perform at the maximum depth of 2000 m.

Pisces IV completed 156 dives in 1980, one of its most active periods. The dives were carried out on behalf of: the universities of Victoria, British Columbia and Calgary; the Environmental Protection Service; Ocean Mixing; Energy, Mines and Resources; and the Institute's Ocean Ecology section. *Pisces IV* also spent a month on contract to B.C. Hydro (Gas Division) surveying the Strait of Georgia for a possible gas line route from the mainland to Vancouver Island. In addition, the submersible repaired a liquid waste outfall at Powell River for the Dillingham Corporation, and retrieved a large quantity of instrumentation for N.O.A.A. in the Strait of Juan de Fuca.

Pilot training was conducted for three new trainees, of which two successfully completed the program.

The first two months of operation were carried out from the MV *Pandora II*, and the remainder of the year from the submersible support barge, *Pender*. This was *Pender's* first "real" year, and she proved to be an excellent substitute when *Pandora II* is not available.

Among the many visitors to dive with *Pisces IV* in 1980 were: Dr. C.R. Mann, Director-General of the Institute; Mr. D. Saxon, Director



Pisces IV

of the Ship Branch; the Hon. Steven Rogers, B.C. Minister of the Environment; and Dr. Max Pavan de Ceccatty of the University of Claude Bernarde, Lyon, France.

A most interesting day was spent in November, when the *Pisces IV* crew was visited by a study group from the Peoples Republic of China. After luncheon was served, two dives enabled four of the eight visitors to experience the submersible's potential at first hand.

1981 promises to be an equally busy year, with *Pisces IV* deployed to the east coast and the eastern Arctic, followed by a mid-life refit on her return to Patricia Bay in November.

Barge *PENDER*

The Barge *Pender* was used as a support and maintenance facility for the *Pisces IV* throughout the year, and offered a unique opportunity for research by Ocean Ecology, by other departments of the federal government, and by the universities of Victoria, British Columbia and Calgary. *Pender* was used as a home base by the Hydrographic Division during May-July, while conducting hydrographic surveys in the Barkley Sound/Broken Islands area.

Institute Workshops

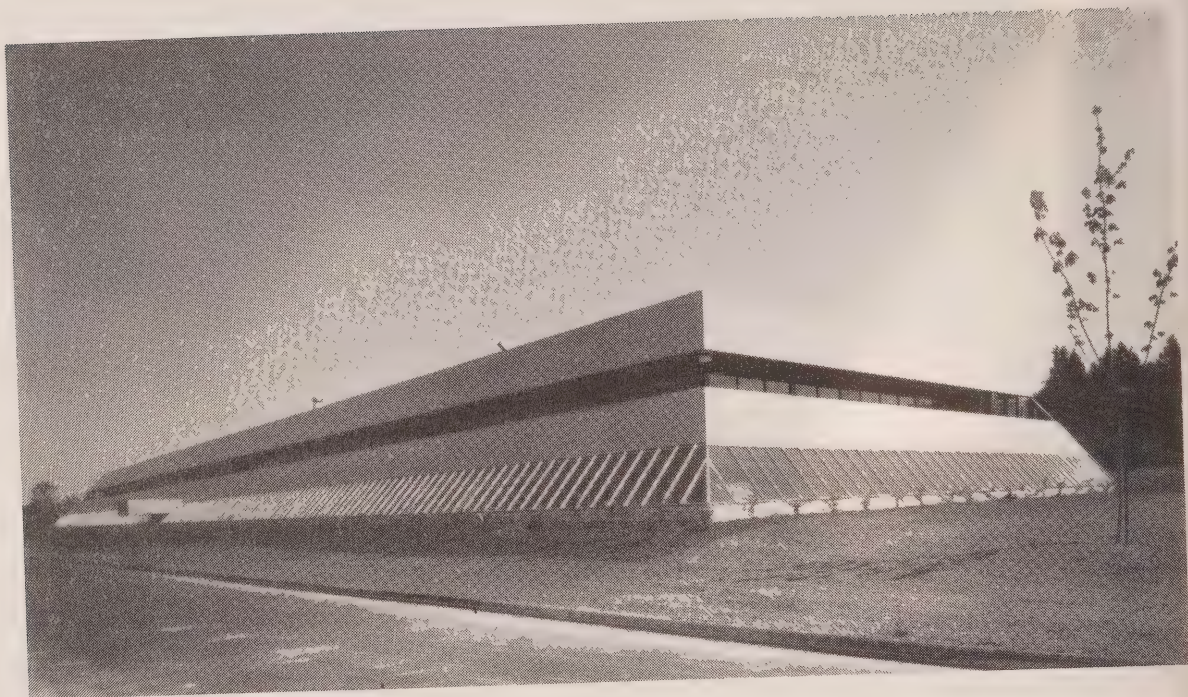
Under the direction of Workshop Supervisor F.V. Smith, a crew of 12 tradesmen and eight helpers maintain a fleet of 35 survey launches and tenders. Our main project this winter is preparing the five survey launches for the HUDSON '81 Arctic survey. This complete overhaul requires the rebuilding of three engines, installation of new gears and vee-drives, a host of interior modifications, two complete re-wiring jobs, and a new paint scheme for easier identification.

In addition to ongoing launch overhaul duties, our shops are in constant demand by the various Institute divisions for steel and aluminium fabrication, special machine shop work, wood and fibreglass projects, numerous pieces of furniture, and sandblasting and painting expertise. The depot also lends support to our larger vessels, *Parizeau*, *Vector*, *Richardson* and the Barge *Pender*.

Deck Machinery

Deck Machinery supplied equipment and services to 154 cruises, and equipment to the Bedford Institute of Oceanography. It also maintains 84 pieces of support gear to service ships for the Institute, the Ministry of Transport, the Department of National Defence, and various contractors.

Management Services



*Marine Technology Centre,
Patricia Bay, B.C.*

During 1980, the last construction package under the main building program was completed. A -50°C environmental chamber with close temperature limits was accepted after tests and is now fully operational. A design study of four solar systems to heat domestic hot water was completed; construction is expected by March, 1981.

Construction of the Marine Technology Centre adjacent to IOS was begun. The building contains more than 40,000 square feet and is being erected by the British Columbia Development Corporation on land leased from the Department of Fisheries and Oceans. It was financed under the joint Federal-Provincial Industrial Development Subsidiary Agreement; occupancy is expected in early 1981.

The region is now linked to the departmental Financial Accounting and Control System (FACS). This is an integrated system which permits financial information on allotments, commitments and expenditures to be retrieved at various management levels throughout the department. The region's previous computerized financial reporting system, which has been in operation for a number of years, was interfaced with FACS so that benefits could be derived from both systems.

During the year, considerable progress was made with the regional materiel inventory system. The region also leased a MICOM word processor system to be used for manuscripts, large volume repetitive work and some computational tasks. Several display models were constructed to illustrate the work and purpose of selected Institute programs. One of the models describes dynamics of fjord circulation, another displays the ocean-atmosphere carbon dioxide cycle, and a third illustrates pingos found on land and under water in the southern Beaufort Sea region. Along with a display from the Pacific Geoscience Centre, these models represented IOS at the B.C. Science Fair held in Vancouver in late October. The models were widely acclaimed for their interest, relevance and artistry, and are now on permanent display at the Institute.

Public interest in the activities of the Institute continued to increase, as evidenced by the well-attended Tuesday and Thursday morning tours led by the Canadian Corps of Commissioners.

After several delays, the library's computer-based catalogue system became a reality. A major portion of the year was devoted to entering the data and making corrections under the three standard categories—author, title and subject. The system is now in use, and the card catalogue has been discontinued.

DEPARTMENT OF THE ENVIRONMENT



NCAR Electra aircraft used during STREX.

Atmospheric Environment Service

Prompted by growing interest in marine meteorology, interactions of the atmosphere and the ocean, and their effects on weather and climate, the Atmospheric Environment Service (AES) of Environment Canada placed Dr. G.A. McBean at IOS in September, 1980. Dr. McBean will be conducting co-operative research with Insitute scientists; the first such joint project is the Storm Transfer and Response Experiment (STREX).

STREX is a Canada-United States study of storms in the northeast Pacific Ocean. Its objective is to understand the processes operating in the atmosphere and ocean, and the exchanges of energy that occur between and during mid-latitude storms. AES and IOS are co-operating with the U.S. agencies, NOAA, NCAR and NASA, and with universities on both sides of the border. AES appointed Dr. McBean lead scientist for the Canadian meteorological program, which was centred on the weathership, CCGS *Vancouver*.

For STREX, the Canadian meteorological program implemented a NAVAID upper-air sounding system, using satellite communication links to a central data processor on the *Vancouver*. This allowed balloon ascents every three hours during storm periods, while also satisfying AES operational requirements. The system also freed the radar from its normal balloon tracking duties. A special antenna controller-data logging system was attached to the radar in order to provide a three-dimensional analysis of radar echoes from precipitation within 150 km of the ship. The surface meteorological program on the ship was further enhanced by installation of additional sensors and a continuous digital recording system. A fourth special system had the capability of launching pressure-temperature-humidity sondes at hourly intervals during selected storm periods.

The data collected from these systems will be processed and analysed in detail during the coming months. The observations taken from the *Vancouver*, in combination with those from other STREX platforms, will allow a detailed investigation into the structure and dynamics of storms and their associated precipitation. Particular areas of interest are boundary layer evolution during fronts, and the interaction of the boundary layers of the atmosphere and ocean with the cloud layer above.

Rapid changes in atmospheric characteristics occur across cold fronts. On November 17, 1980, a cold front moved over the CCGS *Vancouver*, as evidenced by the hourly pressure-temperature-humidity sondes which showed a temperature decrease of almost 4°C in one hour at heights above one km. Closer to the ocean surface, the changes were quite small,

due to the thermal inertia of the ocean. The boundary layer changed from stable to nearly adiabatic, resulting in the development of cumulus clouds behind the front.

As STREX results become more comprehensive, it is expected that significant contributions to the development of weather and climate prediction models will be made. (*Contact: G. McBean.*)

Canadian Wildlife Service

Integration of the various oceanographic disciplines with marine biology is essential for a thorough understanding of how marine life systems interact with physical oceanographic features. Marine birds and mammals and the larger fishes occupy the upper trophic levels of the marine food web. At IOS, Dr. Kees Vermeer of the Canadian Wildlife Service (CWS) examines how the distribution of marine birds relates to that of their food supply, which is in turn governed by climatic, chemical and physical factors. This is essentially a "top-down" approach, in contrast to the "bottom-up" method by which oceanographic information is related to the lower trophic levels of the food web (e.g., plankton).

The integration of both these methods through co-operative and multi-disciplinary studies leads to a better understanding of whole ocean systems. Although multi-disciplinary studies have not been incorporated under a formal rubric at this stage, some inter-departmental programs have been initiated and others are in progress. One such study commenced this spring on plankton-feeding alcids in the Queen Charlotte Islands. The distribution of birds is being examined in relation to that of their plankton prey. Factors which may affect distribution and density of plankton are also being investigated. (*Contacts: Vermeer and Cornford.*)

Rhinoceros Auklet. The feeding habits of this sea-bird are under study, in order to gather information which will help to protect and preserve it.



Two other co-operative studies of IOS and the Pacific Biological Station in Nanaimo are in progress. One focuses on fish-feeding alcids off northern Vancouver Island (*contacts: Vermeer and Westrheim*), and the other on benthos-feeding sea ducks in the Strait of Georgia (*contacts: Bourne and Vermeer*). In addition to population and food chains, the effects of

environmental disturbances on marine birds and their prey is examined. An inquiry into the effects of mine tailings on the Quatsino coastal inlet system is in the planning stage. (*Contacts: Thompson and Vermeer.*)

At IOS, the Canadian Wildlife Service continues to maintain involvement with the Pacific Seabird Group, an international organization which advances information on research and conservation of marine birds in the Pacific. (*Contact: Vermeer.*)

**DEPARTMENT OF
ENERGY, MINES AND RESOURCES**

PACIFIC GEOSCIENCE CENTRE



Pacific Geoscience Centre at IOS.

Earth Physics Branch & Geological Survey of Canada

Chief Scientist's Foreword

In 1978, personnel from the Earth Physics Branch and the Geological Survey of Canada, Department of Energy, Mines and Resources (EMR) were moved to facilities at the Pacific Geoscience Centre (PGC) on the IOS campus. These facilities were designed for EMR programs along the western continental margin, both on- and offshore, and for complementary earth science programs in the British Columbia interior. This 1980 Annual Report of IOS contains the first account of the Pacific Geoscience Centre's programs in those areas.

The purpose of our earth science programs is to provide geological and geophysical information on the conformation, structure, evolution and dynamic processes of the solid earth, and the hazards associated with natural and induced geological processes, with special reference to the western Canadian land mass.

The projects described on the following pages have provided data for the development and extension of ideas about plate motions along the western continental margin. These studies, along with an expansion of the seismological network, have resulted in a better understanding of earthquake mechanisms and frequency.

Studies of geology have been directed toward an understanding of the earth's crust along the margin, and of the deposit, composition and stability of sediments on the continental shelf. Geophysical studies at the margin, and east of it, have included a large gravity survey, geothermal surveys, seismological recordings, and seismological and geomagnetic studies of earth structure.

In pursuing these objectives, scientists at the Pacific Geoscience Centre make use of IOS ships and other facilities such as libraries, computers, shops and administrative functions. Within the PGC wing, seismic, magnetic and gravity tide records are obtained for scientific purposes, and are also on display for public viewing. A common administrative group serves the needs of the two branches, and a pool of technical employees supports the various projects by developing or servicing equipment.

Seismological Service

The Seismological Service provides earth scientists, civil engineers, resource development industries and the public with seismic data, and with research information concerning natural and induced earthquakes, ground motion, seismic risk, earth structure, and nuclear explosions. This is accomplished through a network of seismological stations, including standard and regional stations, two telemetered arrays, strong motion accelographs, and special installations.

Seismic Networks

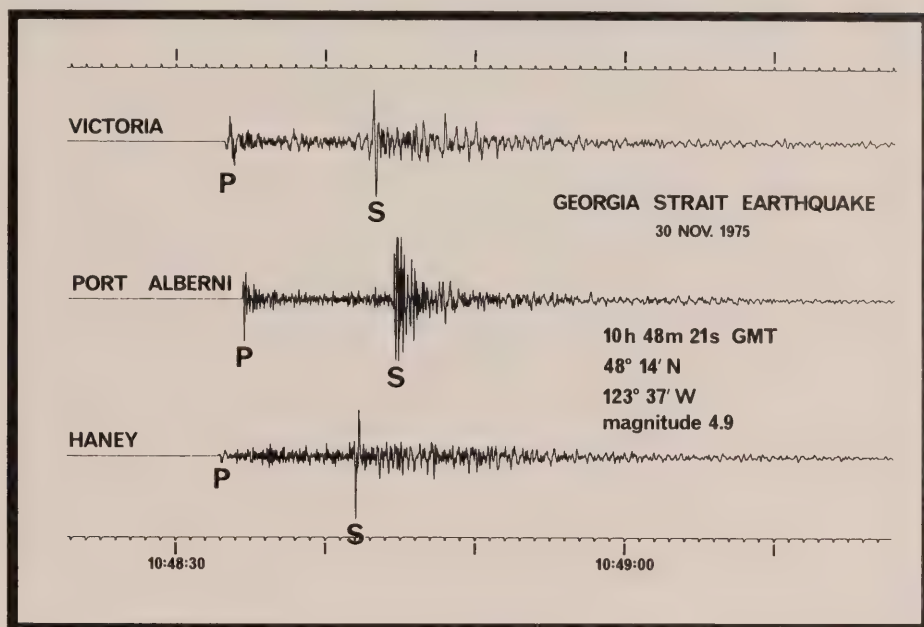
A standard station consists of six seismographs which record north-south, east-west and vertical ground motion in the short (0.3 to 1.0 second) and long (15-40 seconds) period bands. The seismic spectrum is split in this discontinuous fashion due to the strong world-wide noise peak in the six-second range which results from ocean waves. This noise originates at the coastline and is propagated across the continents with little attenuation, since the earth serves as an effective energy wave guide.

Raw and processed data from the network are sent to other national and international scientific agencies. One standard station is operated at IOS. It is open to the public and includes six seismograph recorders for the telemetered arrays, as well as tidal, tiltmeter and geomagnetic field recorders. Other west coast standard stations are at Port Hardy and Penticton.

Regional stations record only vertical short-period motion, which is best suited to local earthquake detection. In the west, they are located at Fort St. James, Mica Creek (near Revelstoke), Gold River on Vancouver Island, Skidegate on the Queen Charlotte Islands, and several locations in the Yukon. A telemetered array located at IOS in southwest British Columbia complements the standard and regional stations in this region of high seismicity and socio-economic importance; it, too, consists only of short-period vertical motion instruments. During 1980, stations were installed at IOS, Haney, Pender Island, and Port Alberni.

During 1980-81, the Haney station was relocated to a quieter and higher site nearby. These data are now telemetered to Saturna Island and relayed to an antenna at IOS. New telemetered stations have been installed on the Sechelt Peninsula, and near Campbell River. The Pender Island station is being relocated to the Saturna Island station. Further expansion is scheduled along the west coast of Vancouver Island and in the Garibaldi volcanic chain; we will also be monitoring two stations installed by the University of British Columbia.

The seismic data from these arrays are first digitized, then telemetered to IOS via telephone and radio. They have the advantages of high reproduction fidelity and high dynamic range (108 decibels), compared with the 40-50 decibels of standard paper seismograms. The range of ground motions which can be recorded is 10 nm/s (10^{-8} m/s) to about one mm/s. Providing immediate identification of earthquake epicentres and magnitudes, these arrays enable researchers to respond quickly in several ways. For example: by deploying additional field instrumentation to study after-shocks, monitor volcanic activity and inform the public about such events.



*Pacific Geoscience Centre
seismic traces.*

Seismograms from the IOS standard station, the regional stations and the telemetered arrays are routinely analysed. Earthquakes located by these means average about two per week, of which five were felt by humans in 1980/81. Four small quakes, although not felt by the public, were right under or very near North Saanich, 15-20 km deep. Beginning in early 1981, the location of all western and Yukon earthquakes will be detectable.

Some forty strong motion accelerographs form a network throughout the lower mainland of British Columbia and the Yukon. These are passive three-component instruments that, when triggered by strong accelerations (e.g., $\frac{1}{2}\%$ or 1% gravity, depending on the setting), record with a sensitivity of $\frac{1}{500} s^2$ on photographic film. If 0.1 mm is considered a useful trace amplitude, this corresponds to $50 mm s^2$ ($\frac{1}{2}\%$ gravity) of ground acceleration. Thus, it is possible to record the earthquake energy spectrum almost continuously, from the quietest seismic background

noise to strong earthquake motions. The strongest acceleration recorded to date occurred in 1976, from an event under Pender Island. In several locations, horizontal measurements were 5-6% gravity, which is considered to be near the damage threshold for buildings.

Finally, data are processed from a special installation consisting of a short-period teleseismic array at Yellowknife. 18 vertical short-period seismometers are linked to a computer which focuses the array on-line, in 121 beams distributed around the world. This installation is the result of Canadian participation in international efforts to detect and discriminate among underground nuclear explosions, in preparation for a comprehensive nuclear test ban.

Seismic Risk Estimation

The data derived from the Canadian seismological network are analysed and stored in the Canadian Earthquake data file. These data supply seismic risk estimates based on extreme value analyses and, along with available general information and earthquake listings, are available to the public on request. New methodology, inclusion of new data, and new understanding of earthquake tectonics are all being used to improve current risk studies. Results, in the form of maps showing peak horizontal ground acceleration and velocity at selected probabilities, have been submitted to the Canadian National Building Code Committee. For example, at IOS there is a 50% probability in a 70-year period of exceeding one m/s of peak horizontal ground acceleration on hard rock. On fill or alluvium, this motion would be amplified.

Special Earthquake Studies

These studies include: a comprehensive review of epicentres, fault mechanisms and magnitudes of the larger historical events; earthquakes in the Puget Sound-Georgia Strait area, southeast British Columbia and on the Queen Charlotte Fault Zone; and the relationship between fault slip earthquakes and plate tectonic models.

Radon Emanation Monitoring

Reports from the U.S.S.R. and China suggest that increases in radon emanation from soil or well water may be a significant earthquake precursor. A radon monitoring program has been supported at the University of British Columbia, and in 1980 a dry hole was drilled at IOS and equipped with etch-track cups for the measurement of radon increases. Efforts to establish the reliability of radon-earthquake relationships will be continued.

Earth Structure by Seismic Methods

One of the most important techniques for determining the deep structure and properties of the earth is the study of waves propagated by explosions or earthquakes. The principles and many of the techniques are similar to those applied by the petroleum industry to the study of sedimentary basins and their structure. The work includes a wide range of theoretical and field investigations, including deep crustal and shallow sedimentary programs. The deep crustal programs are directed mainly toward defining the structure in the principal earthquake generating zones along the continental margin.

Theoretical Studies

The determination of earth properties (structure, velocity, attenuation) by seismic methods is approached in two ways, modeling and inversion. The choice depends on the nature of the data and the amount of information required. In iterative forward modeling, the object is to compare a response that approximates seismic observations with an estimate of its uncertainty. The model is refined by progressively comparing the observed with the predicted wave field. Theoretical frameworks available for this type of modeling are ray, integral and finite difference/finite element methods. All three are used in a variety of modeling problems, including land and marine configurations, laterally homogeneous and heterogeneous structures, and acoustic and elastic wave fields.

Inversion involves an alternate method— extracting information from the data, itself. Currently limited to data from regions that are laterally homogeneous, three theoretical frameworks available are linearized (matrix) inverse, integral, and wavefield transformation methods. In the first two, only a minute (often biased) subset of the data is used; in the third, the entire data wave field is transformed into a solution plane. Although both land and marine data have been inverted, only the second method is currently used at IOS.

Field Studies

In a study undertaken in co-operation with the University of British Columbia's Department of Geophysics and Astronomy and the Atlantic Geoscience Centre, the offshore segment of a major seismic experiment (VISP-80) was designed to determine the deep crustal and upper mantle structure beneath the continental margin of southwestern British

Columbia. With the participation of nine different institutions, a large number of land stations and eight ocean bottom seismographs (OBS) used small explosive shots and a 32-litre airgun to show that oceanic crust is being subducted, or thrust, beneath the continental margin of southwestern British Columbia. This process is responsible for mountain building, volcanic activity, and major earthquake concentrations. A deep reflection experiment was also carried out at the coast, in an attempt to delineate the underlying dipping oceanic plate.

The data from previous temporary land stations and OBS offshore arrays have been analysed to determine the structure and distribution of earthquakes across the Queen Charlotte Islands continental margin. The Queen Charlotte fault zone is the large strike-up boundary between the large Pacific and America lithospheric plates. It has the highest earthquake activity in Canada, and appears to define the oceanic-continental crustal transition.

A suite of 35 seismic reflection profiles which cross the outer continental margin of western Canada at a spacing of about 25 km has been compiled at a common scale with vertical exaggeration. These provide a basic data set for the interpretation of tectonic interaction and sedimentary processes across the margin.

A detailed study of seismic reflection profiles in the area of Dellwood Knolls, an active sea floor spreading centre off northern Vancouver Island, and on the Juan de Fuca ridge has been carried out to examine the dynamics of deep sea lava flows. They show that thin sea floor lava flows can extend tens of kilometres from their sources, moving over gently sloping sedimentary surfaces.

A geophysical data compilation and interpretation of the Winona Basin, a deep trough off northern Vancouver Island, has shown an infill of extremely thick and young sequences of turbidite sediments. The sediments have high seismic velocity because of lithification by carbonate cementation. The basin itself is a consequence of geologically-recent plate boundary reorganization in the area.

Geothermal Studies

The earth's temperature influences both rock properties and geological processes. Thermal data, particularly surface heat flux, are among the most important indicators of deep tectonic processes and the structure of the earth's crust. Most active tectonic processes that result in mountain building, earthquakes and volcanism originate from thermal energy. In addition, the earth has considerable economic potential as a heat source for geothermal energy.

Measured thermal parameters include surface heat flux (the result of vertical temperature gradient multiplied by the thermal conductivity of the rocks), and heat production from natural radioactive decay in crustal rocks (for example, thorium and potassium). Studies cover a wide range of geological and geophysical interest— from heat flow, heat production and thermal processes in the deep sea floor, to the discovery and development of geothermal energy resources in western Canada.

Investigations of heat flow through the ocean crust have been of three different types. First, using the CFAV *Endeavour*, the variability of heat flow has been measured in low permeability sediments covering young oceanographic crust near an outcropping basement ridge. The results indicate a high efficiency of hydrothermal heat transport in cooling young oceanic crust. Second, a detailed heat flow study in the northwestern Atlantic may provide information on thermal aging of the old oceanic lithosphere. Third, heat flow measurements in the sea floor and on land across the Queen Charlotte Fault zone have shown a transition from very high values of heat flow from the oceanic crust to low values on land. No significant frictional heat appears to be generated along this major active fault zone.

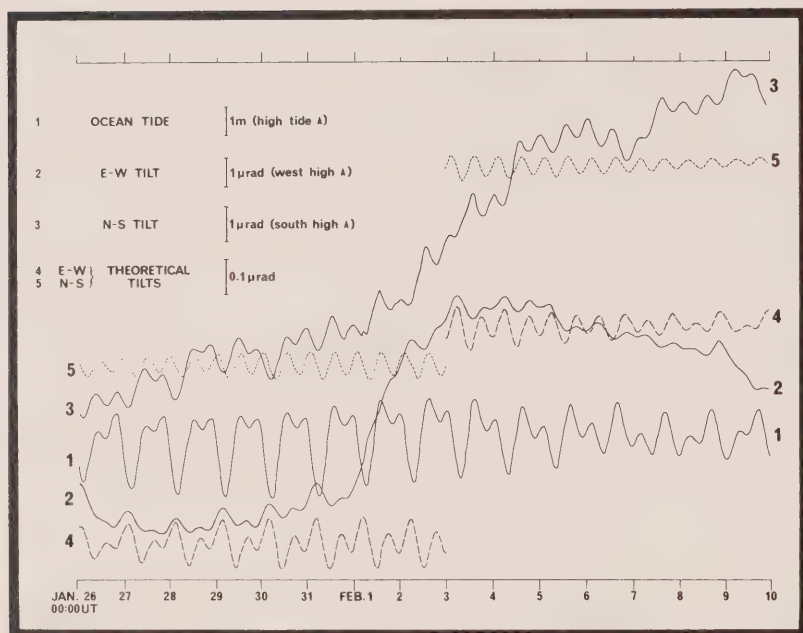
As part of a major study of heat flow variation across the Coast Crystalline Complex, repeat heat flow measurements were taken in Jervis Inlet aboard CSS *Vector*. Heat flow increased by a factor of two along the inlet, although measurements on a large number of representative surface rocks from the Crystalline Complex indicate a generally low heat production.

A new data acquisition system with a storage capacity of 16,000 channels has greatly increased the efficiency of the gamma ray spectrometer, an instrument used for routine heat production measurements within rock samples. Furthermore, the new system permits studies of disequilibrium in the uranium radioactive series, which is particularly useful for radioactive waste disposal studies being conducted on samples from the Lac du Bonnet Batholith.

Geothermal studies provide the basis for geothermal energy discoveries. In the White Lake (Tertiary Penticton Outlier) of southern British Columbia, the variation of heat flow suggests the systematic movement of hot water deep within the basin. Plans are underway to determine the regional heat flow, using drill holes adjacent to two other Tertiary Basins in southern B.C. Temperature measurements in the Garibaldi volcanic belt at Meager Mountain and Mt. Cayley suggest a promising geothermal potential.

Geodynamics

As in the previous three years, work in geodynamics on the west coast has concentrated on precise gravity measurements in the area of central Vancouver Island. The purpose of these measurements is to identify and monitor secular gravity changes which may be associated with crustal strain at a level of a few microgals ($1 \mu\text{Gal} = 10 \text{ nm/s}^2$). Using the new La Coste and Romberg Model-D gravimeter and innovative survey techniques, significant changes in gravity were observed in the Strathcona Park area of Vancouver Island. Although the interpretation of these changes is still speculative, the data suggest that elevation changes on the order of two cm/annum, or regional density changes on the order of 0.01%/annum may be occurring in the Buttle Lake region. The relationship of these changes to contemporary tectonic stress fields and regional seismicity is yet to be determined.



Reproduction of records of the E-W and N-S tilts, and the ocean tide observed at P.G.C., from January 26 to February 10, 1980. The theoretical body tide tilts have been added for comparison.

Note order-of-magnitude difference in scale factors. The large drift beginning on February 1 coincided with a period of heavy precipitation.

Work on the evaluation of the vault piers for the purpose of geodynamic observations was also continued during the past year. This is a prerequisite to the installation of any permanent instrumentation such as tidal gravimeters, tiltmeters, or strainmeters, intended for monitoring the response of the crust to tidal forces and tectonic stress. Tidal gravity data from 1978 and 1979 were analysed and the gravimetric factors for the vault site were determined. The remarkably low value for the M2

gravimetric factor has been interpreted as an ocean loading effect, as opposed to an anomaly in the crustal and mantle structure. Preliminary tilt data also show a dominant influence of local ocean-tide effects, and strong transient signals due to precipitation. The tentative conclusion is that this site is not suitable for the monitoring of the body tide or small secular variations in tilt or strain.

Gravity

The principal mandate of the Gravity and Geodynamic Division is to establish the shape of the geoid in Canada to the highest standards, thus providing a regional data base for the evaluation of crustal structure and density, and for the assessment of resource potential. In the first of two marine gravity programs, three La Coste and Romberg dynamic gravimeters (two "beam" type and one "linear" prototype) were operated on CSS *Parizeau* over a gravity test range off Cape Flattery. In the second program, the meters remained aboard for more extensive comparisons during the Resource Charting cruise off the Queen Charlotte Islands in July and August, 1980.

This series of trials marked the world's first seaborne operation of the new La Coste meter. Several factors made this possible: the almost ideal physical layout of the lower laboratory on the *Parizeau*, close to the ship's centre of movement; the accuracy of the Loran-C/BIONAV system; and the availability of two Earth Physics gravimeters for comparison.

Preliminary assessment of the results indicates that the linear prototype performs as expected, in that errors due to the cross-coupling of the ship movement and the pivoted beam in the gravity sensor were reduced. The successful trials ensure that all future west coast cruises will use this system, and that final survey accuracy will probably be within ± 3 m gal (one part in 300,000 of the earth's gravity).

Regional gravity surveys on land were continued under contract in the Valemont area of British Columbia by Terra Surveys. Using a helicopter equipped with inertial navigation to provide horizontal and vertical control, 200 new stations were observed. Previously unavailable in conventional surveys, the inertial navigation system is being pioneered in this three-year contract, providing results of considerable interest to both industry and government mapping agencies.

Preliminary analysis suggests that, if carefully used, the system can provide the required ± 50 m horizontal and ± 3 m vertical control. Also completed under contract is a new digital terrain file enabling the correction of final gravity readings over the whole of British Columbia and adjacent marine areas (one km grid spacing). This file, expected to have additional uses, will be available shortly.



Reading a gravity meter at a field location.

Structural interpretations of gravity data concentrated on the continental margin near the Queen Charlotte and Scott Islands. Such data provide fundamental constraints on the bulk density and structure of otherwise inaccessible deep features in the earth's crust. In both these areas, depressed oceanic crust overlaid by a considerable thickness of lithified sediments, appears as a strip seaward of the continental slope. Off the Queen Charlotte Islands, this strip appears to coincide with a marine "terrace", whereas it is found within the Winona Basin off the Scott Islands. Further investigation of these strips is planned for the HUDSON '81 program to determine if they are contemporary examples of the "collage" tectonic assemblage which is currently being applied to older parts of the Cordillera and Pacific margin.

Geomagnetism

Temporal variations in the earth's magnetic field provide a source of electromagnetic energy with which to probe the earth's electrical conductivity structure. Zones of high conductivity related to high temperatures and partial melting are used to explore areas of geothermal interest such as volcanic belts. Geomagnetic depth sounding can also determine the thickness of the cold lithospheric plate riding over the asthenosphere, an important parameter in understanding the active tectonic regions dominant on the west coast.

Although useful for determining the electrical conductivity structure, the temporal changes in the magnetic field also contaminate the data obtained in magnetic surveys used in resource charting. Such surveys map aerial changes in the static magnetic field caused by differences in the magnetic properties of the sea floor. The age of the oceanic sea floor, faults and other structural elements can be interpreted from the magnetic maps. To correct the survey data, temporal variations must be determined over the area during the time of the survey.

The 1980 geomagnetic depth sounding experiment was designed to determine the conductivity structure of the oceanic lithosphere, part of Vancouver Island and also the geomagnetic effect at the edge of the shelf. Magnetometers were located across southern Vancouver Island and extended into the offshore by three ocean bottom magnetometers (OBM), deployed in July from the CSS *Parizeau*. The latter sites were at the top and bottom of the continental slope and about 100 km out on four-million-year-old sea floor. The CFAV *Endeavour* recovered two of the units in late August. The missing unit was retrieved from a beach in Washington state a month later. These data are the first geomagnetic information ever obtained across a continental slope, and the results will vastly improve our knowledge of the geomagnetic coast effect and the conductivity structure in the region. The station on four-million-year-old sea floor will further test the model of a cold lithosphere increasing in thickness with age, an hypothesis supported by the 1978 OBM experiment on the Juan de Fuca Ridge.

Recovery of an ocean bottom recording package which has resurfaced on command after a two-week period in water nearly two km deep.



In addition to geomagnetic variation, a magnetic field produced by an oceanographic current (wave) was recorded. This result demonstrates the potential of the instrumentation for measuring mass water transport— a new technique to be exploited in co-operation with oceanographers.

During a 1977 survey, the geomagnetic variations recorded along a profile in western Washington state near Mt. Rainier revealed a concentration of electric current coincident with the Cascade Volcanic Belt. In co-operation with the Geophysics Program at the University of Washington, an experiment with 20 additional sites was carried out in 1979-80. The results indicate that the anomaly extends both to the north and south. The field work ended in mid-May, and the equipment was fortuitously moved from the north slope of Mt. St. Helens two days before the major eruption which occurred there. The increased coverage should enable this anomaly to be correlated with known tectonic features such as the Garibaldi Belt, the extension of the Cascade Volcanics into Canada.

As part of a Canadian network, the Victoria Magnetic Observatory located at the NRC Dominion Astrophysical Observatory site is operated by IOS. The continuous records of the temporal variations in the earth's magnetic field are used for ionospheric studies, and for correction of magnetic anomaly surveys conducted by exploration companies. A recording magnetometer on public display at IOS is used to answer inquiries about the current activity level of the geomagnetic field.

Geological-Geophysical Studies

Natural Resources Charting completed about 8300 km of continuous bathymetric, gravity and magnetic surveys from Hecate Strait, Dixon Entrance and west of the northern Queen Charlotte Islands, out to the 200-mile limit. A few single channel seismic profiles were also obtained. These data determine primarily the crustal structure and the magnetic signature of the sea floor, which define the spreading history of the region beyond the continental margin, and help in understanding the economic potential of the offshore regions.

Biostratigraphic studies of the Jurassic strata of the Queen Charlotte Islands continued. This work has led to the recognition of significant new fossil zones, which expand knowledge of Jurassic stratigraphy and the possible occurrences of hydrocarbons. Biostratigraphically complete Middle- and Early-Jurassic sections have been identified; they will probably become the standard sections for the west coast of North America.

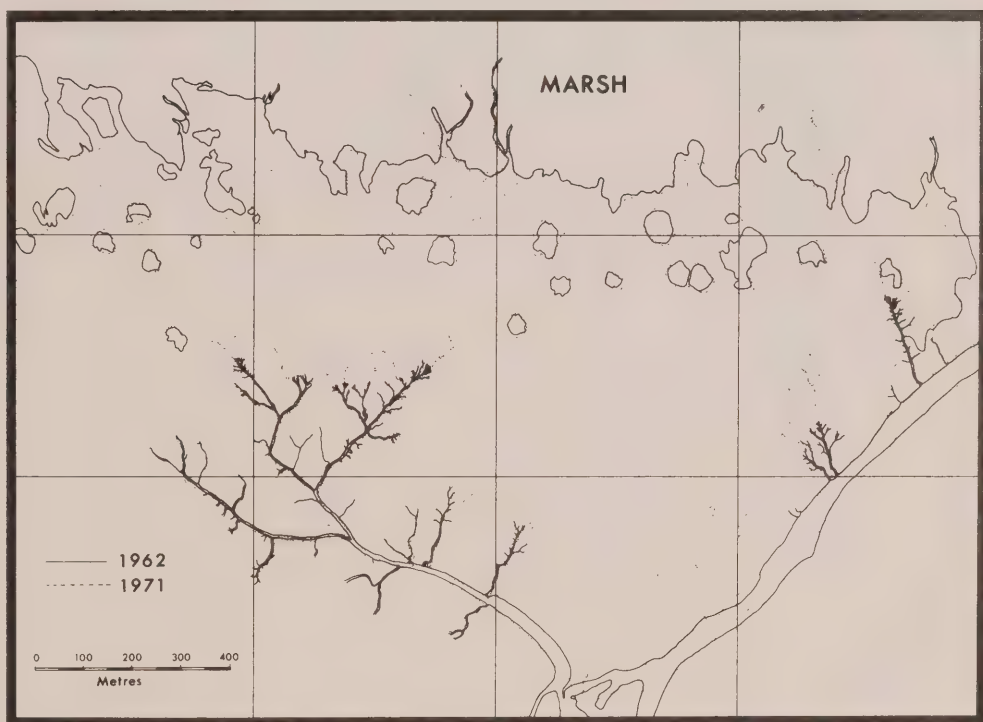
A continuation of detailed sediment and structural studies on the Queen Charlotte Islands has, in conjunction with marine geophysical data, permitted the recognition of allochthonous terrains beneath the continental margin, zones of thermal rifting, and the possibility of

significant petroleum possibilities in southern Hecate Strait and Queen Charlotte Sound.

Sedimentology

Estuarine and Marine Delta Sedimentation

The Fraser Delta has continued to be a major area of study because of ever-growing demands for geological information with which to guide environmental management and industrial development at the delta front. This past year, investigations have centred on defining sedimentation rates (using Pb-210 and C-14 methods) and erosion/deposition patterns (by comparative photogrammetry and comparison of successive echo-sounding surveys). These studies can and have helped to: predict how the stability of the delta front may be affected by natural and man-imposed changes; define the most stable zones for laying exposed cables or pipelines; and identify sites where an experimental program to expand marsh habitats using dredge spoil islands might be performed most successfully.

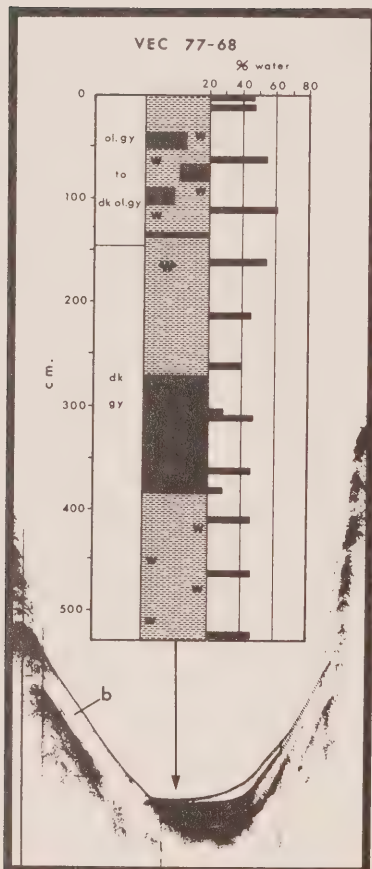


Tidal creek and marsh extension between 1971-72 in area adjacent to the main channel of the Fraser River, and west of Richmond, B.C.

A study is also underway with the Pacific Biological Station and the British Columbia Institute of Technology to map changes in morphology and eel grass coverage on the Nanaimo River delta. This information will contribute to the understanding of natural vs. man-made changes to an important habitat, and help guide rehabilitation of the area.

Fjord Sedimentation

A continuing project is seeking to better understand the processes and post-glacial sedimentary history of British Columbia fjords. As part of this project, a geological and geophysical study of Douglas Channel and Kitimat Arm was undertaken, using low frequency (3.5 kHz) echo-sounding, airgun seismic profiling, and sediment coring. The results show that more than 600 m of sediment have accumulated in the two principle basins, which are separated by a sill composed of morainal materials more than 900 m thick.



Cross-channel, low frequency (3.5 kHz) echo-sounding profile across Douglas Channel, showing the location and descriptive log of core VEC77-68.

In conjunction with information derived from land-based studies by the Geological Survey, it was concluded that much of the sediment in the fjord was deposited during de-glaciation, between 13,000 and 11,000 years ago. Deltaic sedimentation near Kitimat probably began 9000-9500 years ago, leading to the emplacement of the most recent sedimentary units observed in the basins. These consist of stratified muds and sandy muds produced by slumping, debris flows and turbidity currents.

Several types of sedimentary units were identified by seismic profiles and cores: glacial tills; stratified glaciomarine outwash sands and muddy sands; acoustically transparent glaciomarine muds; coarse gravelly morainal sediments; thin surficial, stratified muds and sandy muds with occasional sand layers; and hummocky slump deposits on the Kitimat delta front.

Seismic profiles and maps of sediment distribution and thickness demonstrate that recent sediments in the basins are deposited asymmetrically. These materials, originating principally from the sediment-laden surface water plume and turbid currents moving down the floor of the inlet, are consistently thickest on the north and west sides of the inlet, the result of Coriolis force.

Continental Shelf Sedimentation

Preliminary maps of the distribution of gravel, sand, mud and bedrock have been prepared for the continental shelf off western Vancouver Island, based on grab samples collected on a three km grid. Supplementary information for map construction has come from echo-sounding profiles and sidescan sonographs.

Five distinct areas are identified on the shelf with respect to morphology and sedimentation:

(1) *Scott Islands Carbonate Belt*. This zone of biogenic carbonate (50% CaCO_3), composed predominantly of molluscs, occurs immediately north of the Scott Islands in water up to 130 m deep.

(2) *Northwestern Vancouver Island*. North of Brooks Peninsula, the shelf is characterized by: a narrow inner shelf zone of gravelly sediments; a discontinuous mid-shelf zone of rugged bedrock; a steeply sloping zone of carbonate-rich, rippled sands and gravels; and an outer shelf zone of thin, green, muddy sands overlaying stiff gray muds.

(3) *Kyuquot Uplift*. Immediately south of Brooks Peninsula is a broad region, extending to the shelf edge, of bedrock with thin local patches of rippled sands and gravels.

(4) *Central Vancouver Island*. From Esperanza Inlet to Tofino, the shelf is generally smooth with a gradual and systematic transition from coarse sands and gravels on the inner shelf to muddy sands on the outer shelf.

(5) *Southwestern Vancouver Island*. The region off Barkley Sound is a complex pattern of gravel-topped banks, fringed by sandy sediments, with intervening basins filled with mud. As in other areas, the outer shelf is characterized by thin, green, muddy sands over stiff grey muds.

The topographic simplicity of most of the Vancouver Island shelf suggests that extensive, direct glacial modification was restricted to the southernmost region off Barkley Sound and the Strait of Juan de Fuca. Elsewhere, most of the shelf materials are re-worked glacial outwash and glaciomarine sediments. Unlike the continental shelf off Washington to the south, very little sediment accumulation is taking place today off Vancouver Island; fjords act as important sediment traps, effectively preventing all but the finest materials from reaching the shelf.

Deep Sea Drilling Project

Leg 71 of the Deep Sea Drilling Project in the southwest Atlantic Ocean involved scientists from the United States, Canada, England, France, Russia and Scotland, and focused on two principle problems: the history and initial consequences of Mesozoic rifting, and the opening of the south Atlantic in the vicinity of the Falkland (Malvinas) Plateau; and, fluctuations in the position of the Polar Front, and related changes in productivity and sedimentation during the Cenozoic. Nearly 1300 m of sediment were drilled at four sites during this cruise; the deepest hole reached a sub-bottom depth of 630 m.

Drilling on the Falkland Plateau confirmed that the early opening of the south Atlantic was characterized by restricted circulation and the accumulation of organically rich muds. Major erosion near the Cretaceous-Tertiary boundary was evident; it is related to the opening of Drake Passage.

While the early Tertiary was marked by mild climatic conditions and high sedimentation rates, the Pliocene and Pleistocene were characterized by rapidly deteriorating climate and by frequent and pronounced fluctuations in the Polar Front, bottom current velocities, rates of delivery of ice-rafted detritus, and sedimentation rates. Accumulation rates dropped from 210 m/millennium in the early Pliocene to, at times, less than 10 m/millennium during the Pleistocene.

Coastal Studies

Preliminary work on regional coastal sedimentology and geomorphology of British Columbia began in response to oil spill contingency planning, and to provide baseline planning for industrial and recreational coastal development. Initial aerial reconnaissance and photography of most

of the coastline is complete. These low-angle oblique 35 mm slides, taken at altitudes ranging from 100-400 m, provide nearly continuous coverage of the shoreline and are used in the preparation of sedimentology/geomorphology maps. This information provides the basis for establishing shoreline sensitivity to oil spills, and in planning clean-up procedures should contamination occur.

Research continued at Cape Hatt on the north coast of Baffin Island as part of BIOS (Baffin Island Oil Spill Project). This is an international project designed to analyse the fate and effects of crude oil spilled in Arctic nearshore environments. The results of sedimentological and geomorphological analyses have indicated the probable directions spilled oil would take, and the best areas for each of several types of experiment to be carried out in 1981.

APPENDIX I

CONTRACTS AWARDED

1980/81

<i>Tsunami Digitization Computer Program</i> ABIO Systems Ltd., Victoria, B.C.	\$ 1,300	<i>Preparation of Working Drawings and Specifications for Solar Domestic Hot Water Heating</i> D.W. Thomson Consultants Ltd., Vancouver, B.C.	11,000
<i>Development of Computer Programs for Fluid Problems in Fjords and Coastal Waters</i> CPRO Computing Enterprises, Inc.	24,790	<i>Marine Oligochaeta Identification and Preparation of a Revised Monograph on North Pacific Aquatic Oligochaeta</i> K. Coates, Victoria, B.C.	9,750
<i>Analysis of Seawater and Marine Air Samples from Weatherships and Other Cruises</i> Seakem Oceanography, Sidney, B.C.	52,009	<i>Analysis of AXBT Data from ADAK</i> Interact Computing Services Ltd., Victoria, B.C.	6,003
<i>Analysis of Dissolved Nutrients in Seawater</i> Seakem Oceanography, Sidney, B.C.	10,000	<i>Development and Supply Computer Software</i> Questor Systems, Sidney, B.C.	2,634
<i>Processing of Oceanographic Data from Alberni Inlet</i> Interact Computing Services Ltd., Victoria, B.C.	18,600	<i>Beaufort Sea LORAN-C/ACCUFIX Program</i> INTERNAV Ltd., Sydney, N.S.	22,959
<i>Assembly and Testing of a System for Air/Water/Sediment Studies (Chemcell)</i> Case Existological Laboratory, Victoria, B.C.	24,688	<i>Satellite Remote Sensing of Water Colour and Temperature off West Coast</i> Seakem Oceanography, Sidney, B.C.	76,000
<i>Oceanographic Support to the Institute of Ocean Sciences</i> Dobrocky Seatech, Victoria, B.C.	15,000	<i>Preliminary Design Drawings for C.S.S. Richardson Replacement Vessel</i> Walter S. Hatfield, Vancouver, B.C.	5,500
<i>To Design Soundproof Area on board C.S.S. Parizeau</i> Harford, Kennedy, Wakefield, Victoria, B.C.	1,230	<i>Organolead Production in Marine Sediments</i> Dobrocky Seatech Ltd., Victoria, B.C.	10,131
<i>Analysis of Dissolved Nutrients in Seawater</i> Seakem Oceanography, Sidney, B.C.	10,000	<i>Diving Services in N.W.T.</i> G.C. Jewsbury, Brentwood Bay, B.C.	1,697
<i>Collection, Identification and Enumeration of Marine Zooplankton</i> H.A. Sefton, Victoria, B.C.	6,875	<i>Shipboard Conductivity and Temperature Data Logging System</i> Applied Microsystems, Victoria, B.C.	113,813
<i>Preparation of Scientific Maps and Diagrams from Airborne Survey Data</i> J.B. Kimber, Sidney, B.C.	1,000	<i>Design, Construct Sonar Transducer</i> Mannar Ltd., Cornwall, Ontario	27,000
<i>Collection, Sorting and Identification of Marine Oligochaeta</i> Dobrocky Seatech, Victoria, B.C.	7,025	<i>Beaufort Sea LORAN-C/ACCUFIX Equipment Tests</i> MARINAV Corp., Ottawa, Ontario	23,235
<i>Develop and Supply Computer Software</i> Interact Computing Services Ltd., Victoria, B.C.	1,920	<i>Oceanographic Observations and Analysis aboard the Weathership Quadra</i> H. Ashton, Nanaimo, B.C.	6,000
<i>Development of Computer Programs for Reducing and Processing Satellite Data</i> Apocalypse Enterprises Ltd., Victoria, B.C.	4,380	<i>Oceanographic Data Collection</i> B. Smith, Victoria, B.C.	2,145

<i>Assessment of the Met. Forcing Functions</i> INTERACT Computing Services, Victoria, B.C.	11,160
<i>Provide Scuba Divers for Work on Seafluxes System</i> Broccoli Brothers Enterprises, Sidney, B.C.	240
<i>Oceanographic Data Collection of the Fraser River Estuary and the Strait of Juan de Fuca</i> J. Bruce, Richmond, B.C.	2,975
<i>Oceanic Water Properties Sampling and Measurement Program aboard C.S.S. Parizeau</i> G.C. Jewsbury, Brentwood Bay, B.C.	6,530
<i>Demonstration of Capability of Bottom Detection Techniques to Provide High Quality Digital Depths</i> Meyer Systems, Inc., Vancouver, B.C.	2,000
<i>Preparation of Computer Software Programs for Acquisition and Processing of Salinity-Temperature Data</i> INTERACT Computing Services Ltd., Victoria, B.C. ...	1,333
<i>Analysis of Water Property Data for the West Coast of Vancouver Island</i> J. Papadakis, Victoria, B.C.	10,320
<i>Compilation and Appraisal of Existing Physical Oceanographic Data in the S.E. Beaufort Sea</i> Arctic Sciences Ltd., Sidney, B.C.	13,827
<i>Computer Processing of Oceanographic Data</i> Apocalypse Enterprises, Inc., Victoria, B.C.	4,988
<i>Plot Historical Met. Data from 1969-1979</i> INTERACT Computing Services Ltd., Victoria, B.C.	952
<i>Study of Improved Image Processing on a Standard Microcomputer</i> INTERACT Computing Services Ltd., Victoria, B.C.	500
<i>Coast Projects Ltd., Victoria, B.C.</i>	500
<i>Identification and Enumeration of Phytoplankton Samples</i> Seakem Oceanography, Sidney, B.C.	2,027
<i>Development of a Neutrally Buoyant Sediment Trap</i> Seakem Oceanography, Sidney, B.C.	99,630
<i>Field Testing and Comparison of Shipboard Systems for Locating Drift-Buoys</i> Arctic Sciences Ltd., Sidney, B.C.	19,131
<i>Development, Construction and Testing of a Modified Sonic Oriented C.M. System</i> Caulfield Creative Arts, Sherwood Park, Alberta	53,815
<i>Sample, Identification and Compilation of a Laboratory Key for the Identification of Marine Planktonic Copepods from the West Coast of Vancouver Island</i> EVS Consultants, North Vancouver, B.C.	121,101
<i>Design and Construction of an Electronic Plankton Counting and Sizing System</i> Meyer Systems, Inc., Vancouver, B.C.	19,840
<i>Analysis of Oceanographic Data from Line P and the Coastal Ocean Dynamics Experiment</i> INTERACT Computing Services Ltd., Victoria, B.C. ...	10,480
<i>Investigation of the Feasibility of Mapping Chlorophyll Concentrations from Space</i> CUSS, London, Ontario	59,757
<i>Experimental Investigation into the Accumulation of Cadmium by the Polychaeta Worm, Capitella Capitata, and the Bivalve, Macoma Balthica</i> EVS Consultants, North Vancouver, B.C.	17,368
<i>Edit Tide, Wind and Current Records, etc.</i> Autonetics Research Associates Ltd., Sooke, B.C.	12,500
<i>Study to Develop Methods of Predicting Surface Current in Southern Strait of Georgia</i> Beak Consultants Ltd., Vancouver, B.C.	566,491
<i>Analysis and Improvements of Depth Selection Algorithm for Processing of Hydrographic Field Data Times</i> Questor Systems, Sidney, B.C.	1,575
<i>Identification of Benthic Fauna of Local B.C. Fjords</i> Knoyaton Marine Laboratory, Cowichan Bay, B.C.	3,000
<i>Compilation and Appraisal of Existing Oceanographic and Related Data from the Beaufort Sea</i> Arctic Laboratories, Inuvik, N.W.T.	13,575
<i>Oceanographic Observers aboard C.C.G.S. Quadra Cruise #81-002</i> G. Jewsbury, Victoria, B.C.	6,034
<i>Analyze and Display C.M. Records Obtained in Queen Charlotte Sound, etc., in 1954 by FRB</i> INTERACT Computing Services Ltd., Victoria, B.C. ...	3,000
<i>Explore Possibilities for Using New Techniques, etc.</i> Autonetics Research Associates Ltd., Sooke, B.C.	1,500
<i>Organization and Summary of Ocean Dumping Workshops</i> Dobrocky Seatech, Victoria, B.C.	5,124
<i>Compilation and Analysis of Physical Oceanographic Data in the Channels of the Canadian Arctic Islands</i> Arctic Sciences Ltd., Sidney, B.C.	7,887
<i>Reduction and Analysis of Hydrographic Source Data, and Preparation of a Side Scan Mosaic and a Contoured Field Sheet for the Beaufort Sea PLF Test Area</i> Coast Pilot Ltd., Sidney, B.C.	4,682
<i>Ship of Opportunity Sampling of the Planktonic Ecosystem off the Pacific Coast</i> Broccoli Brothers Enterprises, Sidney, B.C.	49,315
<i>Analysis of Air Expendable Bathythermograph Data from Comox and STREX Missions</i> INTERACT Computing Services Ltd., Victoria, B.C. ...	5,225

<i>Comparison of Wind Measurements Made Using Radar and NAVAID during STREX</i>	
INTERACT Computing Services Ltd., Victoria, B.C. ...	2,420
<i>Data Collection and Review of Criteria for Monitoring National Ocean Dumping Data Base</i>	
EVS Consultants, North Vancouver, B.C.	7,484
<i>Provision of Fortran Programming Services</i>	
INTERACT Computing Services Ltd., Victoria, B.C. ...	7,000
<i>Using Computer Programs for Reducing Data, etc.</i>	
Apocalypse Enterprises, Inc., Victoria, B.C.	1,022

<i>Development of Software System to Archive Hydrographic Field Data Tapes, etc.</i>	
INTERACT Computing Services Ltd., Victoria, B.C. ...	3,666
<i>Data Inventory and Preliminary Evaluation of Fishes in the Canadian Beaufort Sea</i>	
LGL Ltd., Sidney, B.C.	7,500
<i>Preparation of Oceanographic Data and Scientific Diagrams Using Data from Charts, Tables and Records</i>	
C. Wallace, Sidney, B.C.	8,044

APPENDIX II

PUBLICATIONS

A. Department of Fisheries and Oceans

(1) Pacific Marine Science Reports

PMSR 80-1	Giovando, L.F.	<i>Observations of Seawater Temperature and Salinity at British Columbia Shore Stations, 1977</i>
PMSR 80-2	MacDonald, R.W., McLaughlin, F.A., and Page, J.S.	<i>Nutrient Storage by Freezing: Data Report and Statistical Analysis</i>
PMSR 80-3	Thompson, J.A.J., and Paton, D.W.	<i>Further Studies of Copper, Zinc and Cadmium in Molpadia Intermedia from the Point Grey Dumpsite</i>
PMSR 80-4	Mortimer, A., and Milner, P.	<i>Loran-C and Omega Navigation System Tests in the Beaufort Sea</i>
PMSR 80-5	Coastal Zone Oceanography Section (Parts 1 & 2)	<i>Salinity/Temperature Profiles in Saanich Inlet, B.C.</i> Part I: April, 1976-December, 1977 Part II: 1978
PMSR 80-6	Gargett, A.E.	<i>Data Report and Calibrations for Turbulence Measurements in Knight Inlet, B.C., from the Pisces IV Submersible: November, 1978</i>
PMSR 80-7	Tabata, S.	<i>An Inventory of Physical Oceanographic Information for the Waters of Queen Charlotte Sound, Hecate Strait, Dixon Entrance and Their Vicinity</i>
PMSR 80-8	Crawford, W.R.	<i>Sea Level Changes in British Columbia at Periods of Two Days to a Year</i>
PMSR 80-9	Thomson, R.E., and Chow, K.Y.	<i>Butterworth and Lanczos-Window Cosine Digital Filters: With Application to Data Processing on the UNIVAC 1106 Computer</i>
PMSR 80-10	Giovando, L.F.	<i>Observations of Seawater Temperature and Salinity at British Columbia Shore Stations, 1978</i>

PMSR 80-11	Gargett, A.E., Hendricks, P.J., Sanford, T.B., Osborn, T.R., and Williams, A.J. III	<i>A Composite Spectrum of Vertical Shear in the Upper Ocean from the Profilers EMVP, SCIMP and CAMEL</i>
PMSR 80-12	Lake, R.A., and Cooke, R.A.	<i>Calibration Tests on the Conductivity and Temperature Sensors on Modified Aanderaa PCM-4 Recording Current Meters</i>

(2) Contractor Report Series

CSR 80-1	Buckingham, William R.	<i>An Oxygen Budget Study of the Deep Waters in the Inner Basin of Alberni Inlet</i>
CSR 80-2 (Part 1)	Borstad, G.A., and Louttit, G.C.	<i>Ships of Opportunity Feasibility Study. Part 1: Project Evaluation</i>
CSR 80-2 (Part 2)	Louttit, B.C., MacNeill, M.R., Beadall, K.E., Buckley, J.R., and Borstad, G.A.	<i>Ships of Opportunity Feasibility Study. Part 2: Instrument Calibration and Performance, and Computer Software Listings</i>
CSR 80-2 (Part 3)	Borstad, G.A., Louttit, G.C., Gale, R.D., and Buckley, J.R.	<i>Ships of Opportunity Feasibility Study. Part 3: Oceanographic Observations</i>
CSR 80-3	Dobrocky Seatech (various authors)	<i>Kitimat Oceanographic Study, 1977-78</i>
CSR 80-4 (Parts 1-4)	Hutchins, R., Huntce '70 Ltd.	<i>Evaluation of Sonar Equipment and Techniques for Application in the Beaufort Sea: Final Report</i>
CSR 80-5	Barrodale Computing Services Ltd.	<i>Final Report on Statistical Analysis of Pingo-like Features (P.L.F.) in the Beaufort Sea</i>
CSR 80-6	Coast Pilot Ltd.	<i>Study of Pingo-like Features Detected in the Beaufort Sea</i>
CSR 80-7	Simpkin, P.G., Geomarine Associates	<i>Study on the Acoustic Target Strength of the PLFs found in the Beaufort Sea</i>
CSR 80-8	Sallaway, P., Barrodale Computing Services Ltd.	<i>Final Report on Study of Digital Terrain Modeling to Hydrographic Survey Charting Activities</i>

(3) Other Publications, 1980

- BACASTOW, R.W.; J.A. ADAMS, C.D. KEELING, D.J. MOSS, T.P. WHORF and C.S. WONG. 1980. Atmospheric carbon dioxide, the Southern Oscillation and the weak 1975 El Nino. *Science*, **210**: 66-68.
- BAKER, H.R. 1980. A redescription of *Tubificoides pseudogoster* (Dahl) (Oligochaeta: Tubificidae). *Trans. Amer. Micros. Soc.*, **99**(3): 337-342.
- BRINKHURST, R.O. 1980. The production biology of the Tubificidae. *Aquatic Oligochaete Biology*, 205-209.
- BRINKHURST, R.O. 1980. Pollution Biology, The North American Experience. *Aquatic Oligochaete Biology*, 471-475.

- BRINKHURST, R.O. 1980. Postscript. *Aquatic Oligochaete Biology*, 507-514.
- BRINKHURST, R.O. 1980. Taxonomy, pollution and the sludge worm. *Mar. Poll. Bull. (Viewpoint)*, **11**(9): 248-251.
- BRINKHURST, R.O. 1980. Book review of *Pollution ecology of Estuarine Invertebrates*, by C.W. Hart and S.L.H. Fuller. *Science*, **209**: 586.
- BRINKHURST, R.O. and D.G. COOK (Eds.). *Aquatic Oligochaete Biology*. Plenum Press, New York.
- BRINKHURST, RALPH and WAYNE FULTON. 1980. On *Haplotaxis ornamentus* sp. nov. (Oligochaeta, Haplo-taxidae) from Tasmania. *Records of the Queen Victoria Museum*, No. 72.
- CHAPMAN, P.M. and R.O. BRINKHURST. 1980. Salinity tolerance in some selected aquatic oligochaetes. *Int. Rev. Ges. Hydrobiol.* **65**: 499-505.
- CORDES, R.E.; S. POND, B.R. De LANGE BOOM, P.H. LeBLOND and P.B. CREAN. 1980. Estimates of entrainment in the Fraser River plume, British Columbia. *Atmosphere-Ocean*, **18**(1): 15-26.
- CREAN, P.B. (In press). Numerical simulation of the circulation between Vancouver Island and the mainland. *Proc. 3rd International Conference on Applied Mathematical Modelling, University of Hamburg*. Springer-verlag, Hamburg.
- CREAN, P.B. and S. HUGGETT. 1980. On oceanographic conditions about the time of the sinking of the bulk ore carrier *Lee Wang Zin* on 25 December 1979. Report to Canadian Coast Guard.
- CRETNEY, W.J.; P.A. CHRISTENSEN, B.W. McINTYRE and B.R. FOWLER. 1980. Quantification of polycyclic aromatic hydrocarbons in marine environmental samples. In: *Hydrocarbons and Halogenated Hydrocarbons in the Aquatic Environment*, B.K. Afghan and D. Mackay, eds. Plenum Publishing Corp., New York, N.Y., pp. 315-336.
- DENMAN, K.L.; D.L. MACKAS, H.J. FREELAND, M.J. AUSTIN and S.H. HILL. 1980. Persistent upwelling and mesoscale zones of high productivity off the west coast of Vancouver Island, Canada. In: *I.D.O.E. Symposium on Coastal Upwelling proceedings*, edited by F.A. Richards.
- FARMER, D.M. 1980. Mixed layer dynamics in a lake near the temperature of maximum density. *Second International Symposium on Stratified Flows, Vol. 2*, Tapir.
- FARMER, D.M. and J. DUNGAN SMITH. 1980. Generation of lee waves over the sill of Knight Inlet. In: *Fjord Oceanography*, pp. 259-269, edited by H.J. Freeland *et al.*, Plenum Press, New York, N.Y., 715 pp.
- FARMER, D.M. and J. DUNGAN SMITH. 1980. Tidal interaction of stratified flow with a sill in Knight Inlet. *Deep Sea Res.*, **27**(3): 239-254.
- FOREMAN, M.G.G.; L.M. DELVES, I. BARRODALE and R.F. HENRY. 1980. On the use of the Proudman-Heaps tidal theorem. *Geophys. J.R. Astr. Soc.* **63**: 467-478.
- FREELAND, H.J. 1980. The hydrography of Knight Inlet, B.C., in the light of Long's model of fjord circulation. In: *Fjord Oceanography*, pp. 271-276, edited by H.J. Freeland *et al.*, Plenum Press, New York, N.Y., 715 pp.
- FREELAND, H.J. and D.M. FARMER. 1980. Circulation and energetics of a deep, strongly stratified inlet. *Canadian Journal of Fisheries and Aquatic Sciences*. **37**(9): 1398-1410.

- FREELAND, H.J.; D.M. FARMER and C. LEVINGS. 1980. Editors of *Fjord Oceanography*, Plenum Press, New York, 715 pp.
- FRISCH, A.S.; J. HOLBROOK and A.B. AGES. 1980. Effects of a summertime storm surge on the circulation in the Strait of Juan de Fuca. In: *Proceedings of the American Geophysical Union*.
- GARDNER, GRANT A. 1980. A preliminary examination of zooplankton species groupings and associated oceanographically defined regions along the British Columbia mainland coast. In: *Fjord Oceanography*, pp. 407-413, edited by H.J. Freeland *et al.*, Plenum Press, New York, 715 pp.
- GARGETT, A.E. 1980. Turbulence measurements through a train of breaking internal waves in Knight Inlet, British Columbia. In: *Fjord Oceanography*, pp. 277-281, edited by H.J. Freeland *et al.*, Plenum Press, New York, 715 pp.
- GOWER, J.F.R. 1980. Observations of chlorophyll *a* in Saanich Inlet. *Boundary Layer Meteorology*, **18**: 235-245.
- GOWER, J.F.R.; K.L. DENMAN and R.J. HOLYER. 1980. Phytoplankton patchiness indicates the fluctuation spectrum of mesoscale oceanic structure. *Nature*, **288**: 157-159.
- HENRY, R.F. (In press). Richardson-Sielecki Schemes for the shallow water equations, with applications to Kelvin Waves, *J. Comp. Phys.*
- HUGGETT, W.S.; R.E. THOMSON, M.J. WOODWARD, and A.N. DOUGLAS. 1980. *Data record of current observations, Vol. VII, Johnstone Strait, 1976, 1977, 1978*, 288 pp.
- ISEKI, K.; F. WHITNEY and C.S. WONG. 1980. Biochemical changes of sedimented matter in sediment trap in shallow coastal waters. *Bull. Plankton. Soc. Japan*, **27**: 27-36.
- La VIOLETTE, P.E.; S. PETEHERYCH and J.F.R. GOWER. 1980. Oceanographic implications of features in NOAA satellite visible imagery. *Boundary Layer Meteorology*, **18**: 159-175.
- LEWIS, E.L. 1980. The practical salinity scale and its antecedents. *I.E.E.E. Journal of Oceanic Eng.*, **OE5**(1): 3-8.
- LEWIS, E.L. The Arctic Ocean: water masses and energy exchanges. Chapter in book, *The Arctic Ocean: the hydrographic environment and the fate of pollutants*, editor Louis Rey, Macmillan Publishers Ltd.
- LEWIS, E.L. 1980. Oceanographic instrument and deployment system for polar seas. *Oceans '80 I.E.E.E. Publication No. 80CH1572-7*, pp. 7-13.
- LEWIS, E.L. 1980. Air-sea-ice interactions. *Cold Regions Science Technology*, **2**: 329-335.
- LEWIS, E.L. 1980. Water movement in A & Q Fjords near Marmorilik and the processes for pollutant transport. Report written for the Danish Government Fisheries Dep't. on a pollution problem in Greenland associated with the 'Black Angel' Mine.
- LEWIS, E.L. and R.G. PERKIN. (In press). The practical salinity scale 1978: conversion of existing data. *Deep-Sea Research*.
- MELLING, H. and R. LIST. 1980. Characteristics of vertical velocity fluctuations in a convective urban boundary layer. *Journal of Applied Meteorology*, **19**(10): 1184-1195.
- MURTY, T.S. 1980. Residual motion generated by tides in the St. Lawrence Estuary. Pp. 96-101 in *Proceedings of the Oceans-80 Conference, Sept. 6-8, 1980, Seattle*, 563 pp.

- MURTY, T.S.; F.G. BARBER and J.D. TAYLOR. 1980. Role of advective terms in tidally generated residual circulation. *Limnology and Oceanography*, **25**(3): 529-533.
- MURTY, T.S. and M.I. EL-SABH. 1980. Tidally-generated residual motion in the St. Lawrence Estuary. *Proc. of the 13th Annual Simulation Symposium, Tampa, Florida, March 19-21, 1980*, pp. 127-145.
- MURTY, T.S. and H.G. LOOMIS. 1980. A new objective tsunami magnitude scale. *Marine Geodesy*, **4**(3): 267-282.
- MURTY, T.S. and M.C. RASMUSSEN. 1980. Tidally forced stratified flow over sills. In: *Fjord Oceanography*, pp. 173-180, edited by H.J. Freeland *et al.*, Plenum Press, New York, 715 pp.
- MURTY, T.S. and M.C. RASMUSSEN. 1980. Triple-deck analysis for flow over obstacles: Application to internal hydraulic jumps. In: *Proc. of the 2nd Int. Symp. on Innovative Numerical Analysis in Applied Engineering Sciences*, pp. 189-199, edited by R.P. Shaw *et al.*, University Press of Virginia, Charlottesville, 811 pp.
- MACKAS, D. 1980. Zooplankton distribution pattern in the FLEX box, May, 1976: measurements with the electronic plankton counter and comparisons with CPR, UOR and HSLE sampling systems. In: *Proceedings of the final ICES/JONSIS Workshop on JONSDAP 76*, G. Pichot, ed.
- MACKAS, D.; G. LOUTTIT and M. AUSTIN. 1980. Spatial distribution of zooplankton and phytoplankton in British Columbian coastal waters. *Can. J. Fish. Aquatic Sci.*, **37**: 1476-1487.
- O'CONNOR, A.D. 1980. Improving launch echo sounding graphs. CHS Technical Report. IOS, Sidney.
- PERKIN, R.G. and E.L. LEWIS. 1980. The practical salinity scale 1978: Fitting the data. *I.E.E.E. Journal of Oceanic Eng.*, **OE5**(1): 9-16.
- PLATT, T. and K.L. DENMAN. 1980. Patchiness in phytoplankton distribution. In: *The Ecology of Phytoplankton*, pp. 413-431, edited by Ian Morris, Blackwell, Oxford.
- REID, D.B.; A.J. DOW, S.E. MASRY and J.R. GIBSON. 1980. System concept and results of the Canadian aerial hydrography pilot project. In: *Proceedings of the Laser Hydrography Symposium, Adelaide, Australia*.
- SMITH, J. DUNGAN and D.M. FARMER. 1980. Mixing induced by internal hydraulic disturbances in the vicinity of sills. In: *Fjord Oceanography*, pp. 251-257, edited by H.J. Freeland *et al.*, Plenum Press, New York, 715 pp.
- STUCCHI, D.J. 1980. The tidal jet in Rupert-Holberg Inlet. In: *Fjord Oceanography*, pp. 491-497, edited by H.J. Freeland *et al.*, Plenum Press, New York, 715 pp.
- TABATA, S. (In press). On the accuracy of satellite-observed sea-surface temperatures. *Oceanography from Space*, Plenum.
- TABATA, S. and J.F.R. GOWER. 1980. A comparison of ship and satellite measurements of sea surface temperatures off the Pacific coast of Canada. *J. Geophys. Res.*, **85**: 6636-6648.
- TENG, K. 1980. An application of linear programming to selecting Benchmark runs. In: *Proc. of 1980 Conf. of the Canadian Information Processing Society, Victoria*, pp. 56-63.
- THOMPSON, J.A.J. and J.A. CRERAR. 1980. Lead methylation in marine sediments, *Mar. Pollut. Bull.*, **11**: 251-253.
- THOMPSON, J.A.J.; R.W. MACDONALD and C.S. WONG. 1980. Mercury geochemistry in sediments of a contaminated fjord of coastal British Columbia. *Geochem. J. (Japan)*, **14**: 71-82.

- THOMSON, R.E. 1980. Book review of *Waves in Fluids* by James Lighthill, in *Marine Geodesy*, 4(2): 163-164.
- THOMSON, RICHARD E. (In press). Oceanography of the British Columbia Coast. *Canadian special publication of Fisheries and Aquatic Sciences* 56, Dept. of Fisheries and Oceans, Ottawa.
- THOMSON, R.E.; W.S. HUGGETT and L.S.C. KUWAHARA. 1980. *Data record of Current Observations, Vol. VIII, Discovery Passage, Johnstone Strait and Queen Charlotte Strait, Part I— Water property observations, 1976, 1977, 1978 (1979)*, 262 pp.
- THOMSON, R.E.; W.S. HUGGETT and L.S.C. KUWAHARA. 1980. *Data record of Current Observations, Vol. VIII, Discovery Passage, Johnstone Strait and Queen Charlotte Strait, Part 2— Appendices (listing of water property data), Appendices A to E*, 809 pp.
- THOMSON, R.E. and W.S. HUGGETT. 1980. M₂ baroclinic tides in Johnstone Strait, British Columbia. *J. Physical Oceanography*, 10(10): 1509-1539.
- THOMSON, R.E. and L.S.C. KUWAHARA. (In press). Detecting temperature finestructure and mesoscale frontal regimes along Line P in the northeastern Pacific Ocean. *Can. J. Fish and Aquatic Sciences*.
- TOPHAM, D.R. 1980. The disposition of gas-oil mixtures trapped under ice. *Canadian Journal of Physics*, 58(8): 1183-1190.
- TOPHAM, D.R. 1980. The interaction of oil with sea ice in an offshore environment. In: *Offshore Environment in the 80's, a workshop on environmental considerations of East Coast Offshore Hydrocarbon Development*, Dec. 2-4, St. John's, Newfoundland.
- TOPHAM, D.R. and P.R. BISHNOI. 1980. Deep water blowouts. *Proceedings of the 3rd Arctic Marine Oil Spill Program Technical Seminar*, Edmonton, June 3-5.
- WIGEN, S.O. and F.E. STEPHENSON. 1980. Mean sea level on the Canadian west coast. In: *Proceedings of 2nd NAD Symposium, 1980, Ottawa*.
- WONG, C.S.; R.W. MACDONALD, R.D. BELLEGAY and P. ERICKSON. 1980. Baseline data on chemical oceanography in the Southern Beaufort Sea. *Beaufort Sea Technical Report No. 14*, 51 pp.
- WOODWARD, M.J. and W.S. HUGGETT. 1980. Performance of deep subsurface current meter moorings. *Lighthouse, Special Edition— Proceedings of the 19th Annual Canadian Hydrographic Conference*.

B. Department of the Environment Publications

- ALTSHULLER, A.P. and G.A. McBEAN. 1980. Second Report of the U.S.-Canada Research Consultation Group on LRTAP. 40 pp. (available from Environment Canada, Ottawa).
- McBEAN, B.A. (Chairman). 1980. Report of the CAS Working Group on Atmospheric Boundary-Layer Problems, WMO, Geneva. 16 pp. plus four appendices.
- McBEAN, G.A. and J.A. ELLIOTT. 1980. Pressure and humidity effects on optical refractive index fluctuations. *Boundary-Layer Meteorology*, 20: 101-110.
- VERMEER, K. 1980. The importance of timing and type of prey to reproductive success of Rhinoceros Auklets, *Cerorhinca monocerata*, *Ibis*, 122: 343-350.

C. Department of Energy, Mines and Resources Publications

- BORNHOLD, B.D. 1980. Surficial sediments on the continental shelf, northwestern Vancouver Island. *Geological Survey of Canada, Open File 702*.
- BORNHOLD, B.D.; D.L. TIFFIN and R.G. CURRIE. 1980. Trace metal geochemistry of sediments, northeast Pacific Ocean. *Geological Survey of Canada Paper 80-25*: 21 pp.
- CAMERON, B.E.B. 1980. Biostratigraphy and depositional environment of the Escalante and Hesquiat formations (early Tertiary) of the Nootka Sound area, Vancouver Island, B.C. *Geological Survey of Canada Paper 78-9*: 28 pp.
- CLAGUE, J.J. and B.D. BORNHOLD. 1980. Morphology and littoral processes of the Pacific Coast of Canada. In: *The Coastline of Canada*, S.B. McCann (ed.), *Geological Survey of Canada Paper 80-10*: 339-380.
- DAVIS, E.E.; C.R.B. LISTER, U.S. WADE and R.D. HYNDMAN. 1980. Detailed heat flow measurements over the Juan de Fuca ridge system. *J. Geophys. Res.*, **85**: 299-310.
- DeLAURIER, J.M.; E.R. NIBLETT, F. PLET and P.A. CAMFIELD. 1980. Geomagnetic depth sounding over the Central Arctic Islands, Canada. *Can. J. Earth Sci.*, **17**: 1642-1652.
- DRAGERT, H.; L.K. LAW and P.O. SULE. 1980. Magnetotelluric soundings across the Pemberton Volcanic Belt, British Columbia, *Can. J. Earth Sci.*, **17**: 161-167.
- LAW, L.K.; D.R. AULD and J.R. BOOKER. 1980. A geomagnetic variation anomaly coincident with the Cascade volcanic belt. *J. Geophys. Res.*, **85**: 5297-5302.
- LEWIS, T.J. 1980. Determination of radioactive disequilibrium in uranium-bearing rocks: Discussion. *Can. J. Earth Sci.*, **17**: 1114-1116.
- LUDWIG, W.J.; V. KRASHENINNIKOV *et al.* 1980. Southwest Atlantic yields record of its currents. *Geotimes*, **25**: 22-23.
- LUDWIG, W.J.; V. KRASHENINNIKOV *et al.* 1980. Tertiary and Cretaceous paleoenvironments in the southwest Atlantic Ocean: Preliminary results of Deep Sea Drilling Project Leg 71. *Geol. Soc. Amer. Bull.*, **91**: 655-664.
- LUTERNAUER, J.L. 1980. Genesis of morphologic features on the western delta front of the Fraser River, B.C.—status of knowledge. In: *Coastline of Canada*, S.B. McCann, ed., *Geological Survey of Canada Paper 80-10*: 381-396.
- McLAREN, P. 1980. Trends in sediment distribution: a method to predict oil spill movement in the coastal zone. *Spill Technology Newsletter*, Environmental Protection Service, Ottawa, **5**: 76-87.
- RIDDIHOUGH, R.P.; R.G. CURRIE and R.D. HYNDMAN. 1980. The Dellwood Knolls and their role in triple junction tectonics off northern Vancouver Island. *Can. J. Earth Sci.*, **17**: 577-593.
- RIDDIHOUGH, R.P. 1980. Gorda plate movements from magnetic anomaly analysis. *Earth Plan. Sci. Letts.*, **51**: 163-170.

- ROGERS, G.C. 1980. A documentation of soil failure during the British Columbia earthquake of 23 June, 1946. *Canadian Geotechnical Journal*, **17**: 122-127.
- ROGERS, G.C. 1980. Juan de Fuca Plate Map-Seismicity. *Earth Physics Branch Open File No. 80-3*, Department of Energy, Mines and Resources, Canada.
- ROGERS, G.C. 1980. Juan de Fuca Plate Map-Fault Plane Solutions. *Earth Physics Branch Open File No. 80-4*, Department of Energy, Mines and Resources, Canada.
- ROGERS, G.C.; R.M. ELLIS and H.S. HASEGAWA. 1980. The McNaughton Lake earthquake of May 14, 1978. *Bulletin of the Seismological Society of America*, **70**: 1771-1786.
- ROGERS, G.C. 1980. Juan de Fuca Plate Map-Permanent Seismograph Stations (operating January 1, 1980). *Seismological Service of Canada Internal Report 80-4*.
- TIPPER, H.W. and B.E.B. CAMERON. 1980. Stratigraphy and paleontology of the Upper Yakoun Formation (Jurassic) in Alliford Bay Syncline, Queen Charlotte Islands, British Columbia. *Geological Survey of Canada Paper 80-1C*: 37-44.
- WEICHERT, D.H. 1980. Estimation of the earthquake recurrence parameters for unequal observation periods for different magnitudes. *Seismological Society of America Bulletin*, **70**: 1337-1346.
- WEICHERT, D.H. and W.G. MILNE. 1980. A reply to "Comments on Canadian methodologies of probabilistic seismic risk estimation." *Seismological Society of America Bulletin*, **70**: 935.
- WEICHERT, D.H. and W.G. MILNE. 1980. Canadian strong motion records. *Seismological Service of Canada, E.P.B. Open File No. 80-1*.
- WRIGHT, J.A.; A.M. JESSOP, A.S. JUDGE and T.J. LEWIS. 1980. Geothermal measurements in Newfoundland. *Can. J. Earth Sci.*, **17**: 1370-1376.
- YORATH, C.J. 1980. The Apollo structure in Tofino Basin, Canadian Pacific continental margin. *Can. J. Earth Sci.*, **17**: 758-775.

APPENDIX III

PERMANENT STAFF, 1980

Institute of Ocean Sciences

A. Department of Fisheries and Oceans

Director General

Mann, C.R.; B.Sc., M.Sc.(N.Z.), Ph.D.(Brit. Col.), D.Eng.(N.S. Tech.), FRSC

Management Services Division

Chief of Division:

Todd, N.A.; B.Sc.(Glasgow), M.A.(Carleton)

Batchelor, R.J.
Clapp, L.A.
Coldwell, J.H.
Cooper, B.J.
Craton, M.I.K.
Curtis, J.N.
Deane, G.J.
Delacretaz, A.
*Deput, R.M.
Doxey, K.
Doyle, D.A.
Drysdale, A.E.
Firth, C.
Hall, E.J.
Lackner, R.C.
Lalonde, M.T.
Lapp, B.I.; B.A.(Victoria)
Lohrmann, B.A.; B.Sc.(Guelph)
Mathias, A.L.
*McDougal, A.J.
McKenzie, S.D.
Parsons, J.E.
Peirson, E.
Poulin, J.G.
Reinstein, H.G.

Sabourin, J.T.
*Shaw, K.D.
Simington, V.L.
Thomson, L.S.C.; B.A.(Sask.), B.L.S.(B.C.)
Tillie, D.G.
Van Dusen, T.S.
Wonnacott, D.C.

**Left during 1980*

Commissionaires

Sgt. D.W. Price
Sgt. W.L. Caldwell
Comm. G. Bradshaw
Comm. Gessner
Comm. G. Glass
Comm. S. McMillen
Comm. H. Moffat
Comm. P. Osborne
Comm. J. Quinton
Comm. A. Samouelle
Comm. J. Selman
Comm. L. Trerice

Personnel

Regional Personnel Manager:

Hamilton, K.R.; B.A.(Brit. Col.)

Knapp, B.M.
Lafortune, A.J.; B.A.(Manitoba)
Olauson, E.J.
Stevens, I.B.; CIMA (McMaster)

Hydrographic Division

Director of Hydrography:

Bolton, M.

Ages, A.B.; B.A.Sc., M.A.Sc.(Brit. Col.), P.Eng.
Bell, R.D.

- **Brown, M.**
 Brown, R.E.
 Browning, P.C.
 Chan, G.L.
****Chapeskie, R.**
 Coldham, F.A.
 Crawford, W.R.
 B.Sc., M.A.Sc.(Waterloo), Ph.D.(Brit. Col.)
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 Crowther, W.S.
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 Dorosh, L.W.; Dip. BCIT
 Dow, A.J.; P.Eng.(UNB)
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 Eaton, G.H.; B.Sc.(UNB)
 Ellison, G.
 Farmer, M.
 Fisher, D.L.
 Galloway, J.L.;
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 Gould, J.
****Gradwell, K.**
*****Gregson, D.J.; Dip. BCIT**
****Halcro, K.; Dip. BCIT**
***Harris, W.J.**
 Harrison, D.
 Hermiston, F.V.
 Hinds, E.W.; Dip. BCIT
 Hohl, M.
 Hollinger, C.; Dip. BCIT
 Holman, K.R.
 Huggett, W.S.; Master, (FG)
****Jennings, M.**
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 Kenny, B.
****Kidson, G.**
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 Larkin, J.B.; B.Sc.(PEI)
 Lee, K.S.
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 Lusk, B.M.; Master, (350 T)
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 O'Connor, A.D.; Mate (HT) (U.K.), Master, (350 T)
 Osborne, M.
****Parks, J.R.; B.A.Sc. (EE) (Brit. Col.)**
 Patton, M.M.
 Philp, A.R.
 Pickell, L.M.
 Pierce, R.A.
****Pite, H.**
 Popejoy, R.D.
***Preece, M.L.; Dip. BCIT**
 Rapatz, W.J.; B.Sc.(Victoria)
 Raymond, A.R.; Dip. (Algonquin College)
 Richardson, G.E.
****Roberts, J.N.; Master (FG), Cdr. RCN (Ret'd.)**
 Ross, A.D.; CC (Ont. Inst. of Chartered Cartographers)
***Said, N.A.**
 Sandilands, R.W.; Lt. (H) RN (Ret'd.) FRGS
 Sargent, E.D.; Dip. BCIT
***Schoenrank, R.U.; B.Sc.(Victoria)**
****Schofield, A.**
 Smedley, A.J.; LCdr. RCN (Ret'd.)
 Smith, A.; Master (FG)
***Smith, G.R.; B.A.Sc. (ME) (Brit. Col.), P.Eng.**
 Steeples, J.; Cert. Mech. Eng.(Edinburgh)
 Stephenson, F.E.; B.Sc.(Victoria)
***Stone, M.; Dip. (Camosun Coll.)**
 Tamasi, C.R.; Dip. BCIT
 Taylor, R.G.
 Taylor, W.R.; Dip. RCC
 Thompson, L.G.
 Van Duin, W.P.; Dip. BCIT
 Vosburgh, J.A.; Dip. BCIT
 Wakefield, L.M.
 Ward, M.M.; Dip. BCIT, B.A. (Geog.)
 Watt, B.M.
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***Wood, D.J.; Dip. BCIT**
*****Woods, M.V.; Dip. BCIT**
 Woodward, M.J.; B.Sc.(Victoria), M.Sc.(Toronto)
****Yee, J.**

**Left during 1980*
***Joined during 1980*
****Educational leave*

Ship Division

Regional Marine Superintendent: Geldart, E.N.

1st Class Marine Engineer; Fellow, Institute of
Marine Engineers

Parkinson, R.W.; Acting Appointment Regional Marine
Superintendent; Engineer 1st Class Combined;
Assistant Marine Superintendent (Engineering), M.I.M.E.

Fitch, L.A.H.; Master H.T.; Ass't. Marine Sup't. (Deck)

Smith, F.V.; Marine and Industrial Electrician;
Depot Supervisor

Redman, D.J.; Design Draftsman; O.N.C.

Periera, P.; Relief Chief Engineer; 1st Class Motor

CSS PARIZEAU

Newton, B.L.; Master F.G.; Master

Buchan, J.; Master F.G.; 1st Officer

Butler, K.; Master F.G.; 2nd Officer

Palmer, S.; Supply Officer

Olcen, P.; Engineer 1st Class Motor, Chief Engineer

Trant, R.; Engineer 3rd Class Motor,

Senior Second Engineer

Andersen, A.; Engineer 3rd Class Steam, 4th Class Motor,
Second Engineer

Stanway, J.D.; Engineer 4th Class Motor, Third Engineer

Greening, M.; Engineer 4th Class Motor, Fourth Engineer

CSS VECTOR

Sjoholm, K.; Master F.G.; Master

Wheeler, M.G.; Master, H.T.; 1st Officer

Campbell, J.; Mate H.T.; 2nd Officer

Pearson, R.; A/Chief Engineer,

Engineer 3rd Class Motor

Foley, R.; Engineer 4th Class Combined;

2nd Engineer

CSS RICHARDSON

MacKenzie, R.; Master H.T.; Master

Burrell, R.; Engineer 4th Class Motor; Chief Engineer

M.V. PANDORA II (*Charter*)

Jones, R.; Master

Newton, J.; Chief Engineer

PISCES IV

Chambers, F.J.; Chief Pilot

Taylor, R.H.; Pilot

Witcombe, A.; Pilot

Oszust, J.; Pilot

Thomas, G.; Pilot

*Left in 1980

Oceanographic Information Division

Chief of Division:

Cornford, A.B.; B.Sc.(McMaster), Ph.D.(Brit. Col.)

Herlinveaux, R.H.

Smiley, B.D.; B.Sc., M.Sc.(Alberta)

Ocean Chemistry Division

Chief of Division:

Wong, C.S.; B.Sc., M.Sc.(Hong Kong), Ph.D.(Scripps),
Dip. Mar.Sc. (UNESCO), FRSC (U.K.)

Bellegay, R.D.; Dip. NAIT, Assoc. Deg. in Oceanography
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Cretney, W.J.; B.Sc., Ph.D.(Brit. Col.)

Johnson, W.K.; Dip. BCIT

Macdonald, D.M.; B.A.Sc.(Brit. Col.)

Macdonald, R.W.; B.Sc., Ph.D.(Dalhousie)

McLaughlin, F.A.; B.Sc.(Victoria)

Munro, P.S.; B.Sc.(Queen's)

Paton, D.W.; B.Sc.(Brit. Col.)

Soutar, T.J.; Dip. BCIT

Thompson, J.A.J.; B.Sc.(McMaster), Ph.D. (Alberta)

Whitney, F.A.; B.Sc.(Brit. Col.)

Ocean Physics Division

Chief of Division:

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Bell, W.H.; B.A.Sc.(Brit. Col.), M.Sc.(Hawaii), P.Eng.
Bigham, R.W.

Chase, G.W.; Dip. BCIT

Cooke, R.A.; Dip. RCC

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Ph.D.(Liverpool)

de Jong, C.

Farmer, D.M.; B.Com., M.Sc.(McGill), Ph.D.(Brit. Col.)

Freeland, H.J.; B.A.(Essex), Ph.D.(Dalhousie)

Gargett, A.E.; B.Sc.(Manitoba), Ph.D.(Brit. Col.)

Giovando, L.F.; B.A., M.A., Ph.D.(Brit. Col.)

Gower, J.F.R.; B.A., M.A., Ph.D.(Cantab)

Henry, R.F.; B.Sc.(Edinburgh), Ph.D.(Cantab)

Johnston, P.

Kamitakahara, G.R.; B.Sc.(Toronto)

Koppel, A.W.

Kimber, P.M.

Kuwahara, L.S.C.; B.Sc.(Brit. Col.)

Lake, R.A.; B.Sc.(Brit. Col.), M.Sc.(Washington)
 Lee, A.Y.P.; B.Sc.(Victoria)
 Lewis, E.L.; B.Sc., M.Sc., Ph.D.(London)
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 McNeill, J.M.
 Meikle, J.H.
 Melling, H.; B.Sc., M.Sc., Ph.D.(Toronto)
 Minkley, B.G.; Dip. BCIT
 Miyake, M.; B.S.(EE) (Drexel),
 M.S., Ph.D.(Washington)
 Moorhouse, S.W.
 Murty, T.S.; B.Sc., M.Sc.(Andhra),
 M.S., Ph.D.(Chicago)
 Perkin, R.G.; B.A.Sc., M.Sc.(Brit. Col.)

Richards, D.L.
 *Sieberg, D.G.; Dip. VVI
 **Smiley, B.D.; B.Sc., M.Sc.(Alberta)
 Spearing, L.A.F.; B.Sc.(Brit. Col.)
 Stickland, J.A.
 Stucchi, D.J.; B.A.Sc.(York), M.Sc.(Dalhousie)
 Sudar, R.B.; B.A.Sc.(Toronto)
 Tabata, S.; B.A., M.A.(Brit. Col.), D.Sc.(Tokyo)
 Teichrob, R.C.; Dip. BCIT
 Thomson, R.E.; B.Sc., Ph.D.(Brit. Col.)
 Topham, D.R.; D.L.C., D.C.A.E., Ph.D.(Loughborough)
 Wallace, J.S.

*Left during 1980

**Transferred to Ocean Information Division in 1980

Computing Services

Head:

Teng, K.; B.A.Sc., M.A.(Brit. Col.)

Butcher, J.W.; B.Sc.(Victoria), M.Sc.(Toronto)
 Douglas, A.N.; B.Sc.(Victoria)
 Foreman, M.G.; B.Sc.(Queen's), M.Sc.(Victoria)
 Johns, R.E.; B.Sc.(Victoria), M.Sc.(Brit. Col.)
 *Lee, D.K.; B.S.(Chosun-Korea), M.S.(Oregon)
 Lee, K.S.; B.Sc.(Victoria)
 Linguanti, J.; B.Sc.(Victoria)
 Oraas, S.R.; B.A.Sc., M.A.Sc.(Brit. Col.)
 Page, J.S.; B.Sc.(Brit. Col.)
 **Richards, P.J.; B.Sc.(Brit. Col.)
 **Smith, D.B.; B.Sc.(Victoria)
 Wharton, A.H.; B.Sc.(Victoria)
 Woollard, A.L.; B.Sc.(Victoria)

*Joined in 1980

**Left in 1980

Ocean Ecology Division

Chief of Division:

Brinkhurst, R.O.; B.Sc., Ph.D., D.Sc.(London)

*Austin, M.J.; B.Sc.(Brit. Col.)

Coates, K.; B.Sc.(Toronto), M.Sc.(Victoria)

Denman, K.L.; B.Sc.(Calgary), Ph.D.(Brit. Col.)

Forbes, R.; B.Sc.(Carlton), M.Sc.(Alberta)

**Herlinveaux, R.H.

Hill, S.H.; B.Sc.(Brit. Col.), M.Sc.(Victoria)

**Left in 1980*

Mackas, D.L.; B.S., M.S.(Washington), Ph.D.(Dalhousie) ***Transferred to Ocean Information Division in 1980*

B. Department of the Environment

Atmospheric Environment Service

McBean, G.A.; B.Sc.(Brit. Col.), M.Sc.(McGill), Ph.D.(Brit. Col.)

Canadian Wildlife Service

Vermeer, K.; B.Sc., M.Sc.(Brit. Col.), Ph.D.(Alberta)

C. Department of Energy, Mines and Resources

Pacific Geoscience Centre

Chief Scientist:

Milne, W.G.; B.A.(Toronto), M.A.(California), Ph.D.(Univ. of Western Ontario)

Administrative Group

Fyfe, K.; Head

Chisholm, D.M.

**Denney, C.E.

Technical Support Group

Bone, M.N.; Head, B.A.Sc.(Toronto)

Bennetts, H.J.

Bunyan, T.C.

Whitford, H.A.

Marine Geology and Geophysics Section

Yorath, C.J.; Head, B.Sc.(Brit. Col.), M.Sc.(Alberta),
Ph.D.(Queen's)

Bornhold, B.C.; B.Sc.(Waterloo), M.A.(Duke),
Ph.D.(M.I.T.— Wood's Hole)

Cameron, B.E.B.; B.Sc., M.Sc.(Alberta),
Ph.D.(Stanford)

Currie, R.G.; B.Sc., M.Sc.(Brit. Col.)

Frydecky, I.I.; B.A.Sc., M.A.Sc.(Brit. Col.)

Luternauer, J.L.; B.A.(Colby), M.A.(Duke),
Ph.D.(Brit. Col.)

McLaren, P.; B.Sc., M.Sc.(Calgary),
Ph.D.(South Carolina)

**Mangin, M.; B.Sc.(Brit. Col.)

Sarracino, L.

Seeman, D.; B.Sc.(Brit. Col.)

*Tiffin, D.L.; B.A.Sc., Ph.D.(Brit. Col.)

Geodynamics Group

Dragert, H.; Head, B.Sc.(Toronto), M.Sc.,
Ph.D.(Brit. Col.)

Geomagnetic Group

Law, L.L.; Head, B.A.Sc.(Toronto),
M.Sc.(U. of Western Ontario), Ph.D.(Cantab)
Auld, D.R.; B.A.Sc.(Brit. Col.)
DeLaurier, J.M.; B.Sc.(Queen's)

Geothermal Group

Lewis, T.L.; Head, B.A.Sc., M.Sc.(Brit. Col.),
Ph.D.(U. of Western Ontario)

Gravity Group

Riddihough, R.P.; Head, B.Sc.(Kings College, London),
DIC, M.Sc.(Imperial Col., London),
Ph.D.(U. of London)
Price, W.
Stephens, L.E.; B.Sc., M.Sc.(Queen's)

Seismic Hazards

Weichert, D.H.; Head, B.A.Sc., M.Sc., Ph.D.(Brit. Col.)
Gregory, M.J.
Rogers, G.C.; B.Sc.(Brit. Col.), M.Sc.(U. of Hawaii)

Seismic Structure

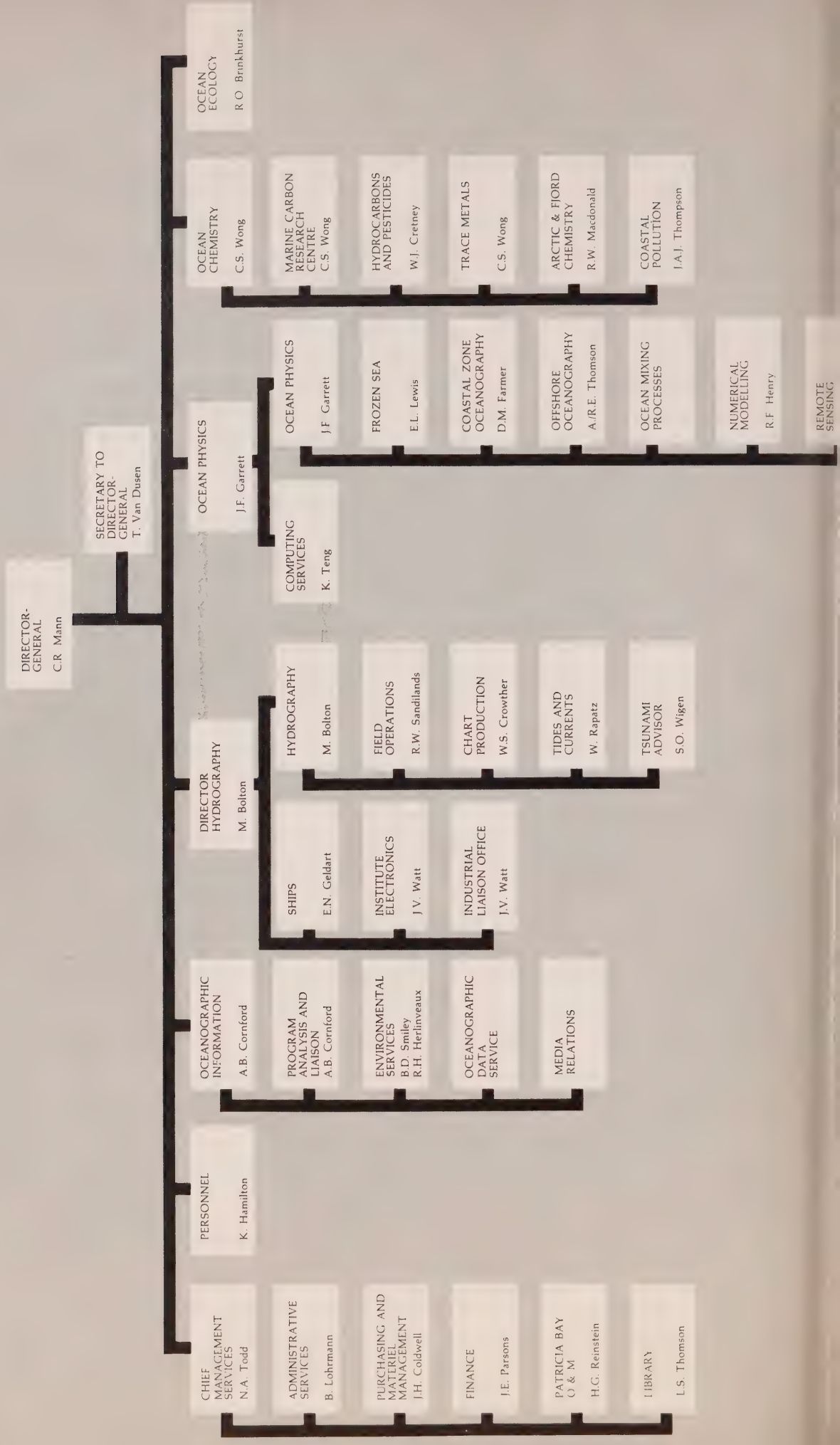
Hyndman, R.D.; Head, B.A.Sc., M.A.Sc.(Brit. Col.),
Ph.D. (A.N.U.)
McMechan, G.A.; B.A.Sc.(Brit. Col.), M.Sc.(Toronto)

**Left during 1980*

***Joined during 1980*

Organization Chart

Department of Fisheries and Oceans



1980 ANNUAL REPORT



Government
of Canada

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PATRICIA BAY, SIDNEY, B.C.

CAI
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- A56

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1981
ANNUAL REVIEW
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DEPARTMENT OF FISHERIES AND OCEANS

Director-General's Foreword

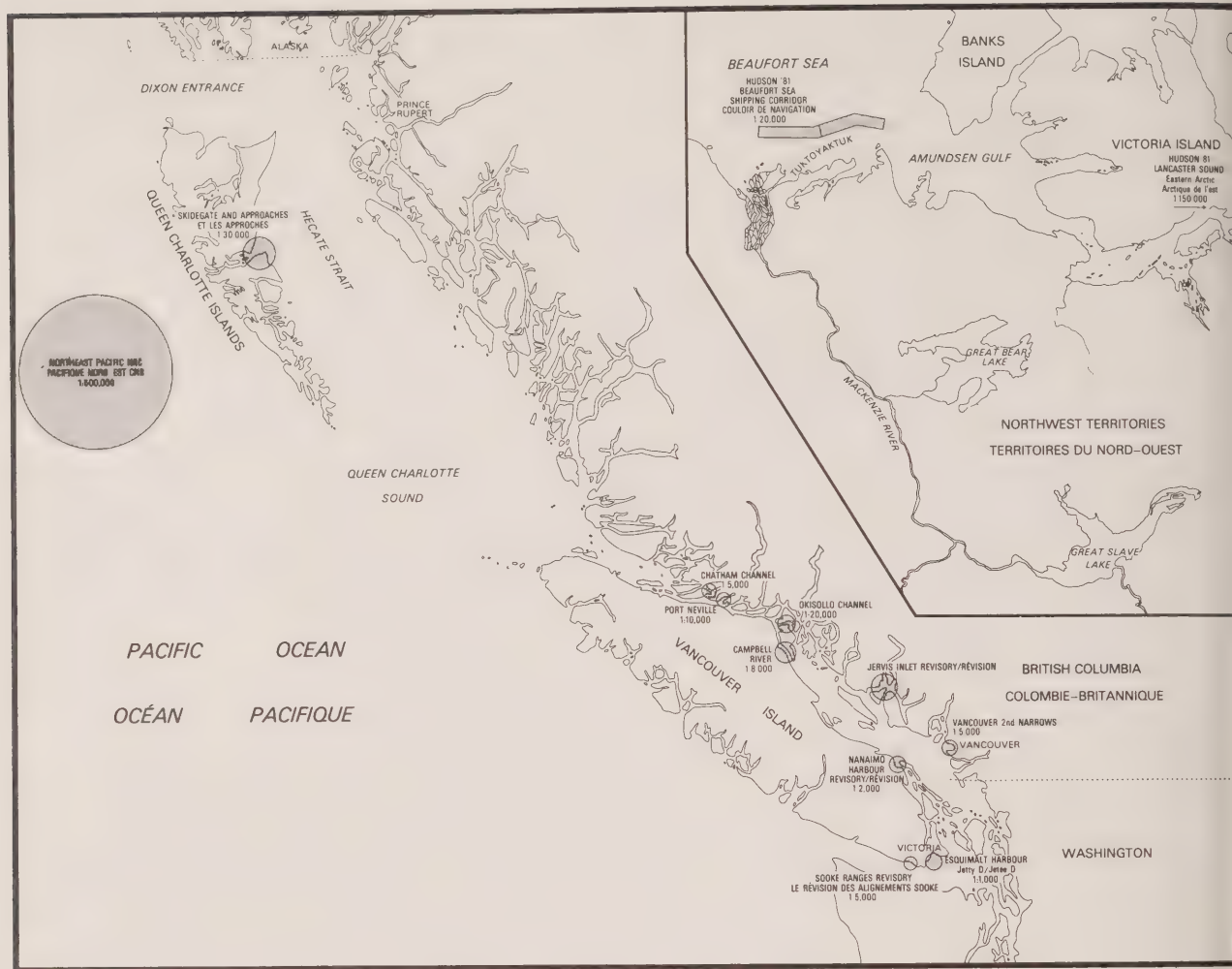
One of the tasks of Ocean Science and Surveys Pacific is to respond to problems arising in the development of natural resources that require hydrographic and oceanographic knowledge for their solution. In 1981 OSS Pacific became involved in two major projects of this type both of which will require substantial effort for the next 3 - 4 years. Provision of hydrographic information to enable safe passage of tankers from the Beaufort Sea to the east is one of these; an assessment of the impact, on the ocean environment, of tailings released into Alice Arm from a molybdenum mine is the other.

Tankers moving eastward in the Beaufort Sea to the Northwest Passage cross areas where pingos create shoals that are a hazard to these large vessels. With production of oil envisioned in the near future it has become necessary to survey a lane through which the vessels may pass safely. A corridor ten miles wide was chosen, and the survey started in summer of 1981 with CSS *Hudson* on loan from the Bedford Institute of Oceanography. Fifty percent of the corridor was surveyed and it is planned to continue in succeeding years with charter vessels.

Deposition of tailings from the AMAX molybdenum mine into Alice Arm Inlet commenced early this year. The disposal of the tailings into the inlet caused concern that they could adversely affect the environment and local fisheries. A first response to this has been to monitor the tailings' plume to see that its depth and extent conformed with guidelines previously specified. Following the monitoring a three year research program was started to look at basic problems in dispersal of mine tailings in an inlet using the plume in Alice Arm as a case history.

The above projects, together with other responses to practical problems, meant that the region placed considerable emphasis on applied research and survey during 1981. However, it is not intended that the region should diminish its long term effort devoted to understanding the ocean and to improving techniques of measurement and survey. Considerable progress in these areas has been made throughout the year; the improved knowledge of the waters of the continental shelf acquired through the CODE experiment, and major developments in automated cartography, are examples. Physical oceanography has been strengthened with the addition of two theoreticians to better balance the total effort in physics, but progress in chemical and biological oceanography is disappointingly slow due to the very small staffs in these two divisions. I am hopeful that this will be recognized and the resources necessary to develop both disciplines made available in the future.

Hydrography



Pacific Region 1981 hydrographic survey program.

The main objective of the Hydrographic Division is to provide accurate, timely bathymetric and navigational information in the form of nautical charts, tide tables, and sailing directions for commercial and recreational users. Additional data are provided to other federal agencies, industry, universities, environment groups, and the general public.

The Division carried out activities in the following important areas in 1981: surveys by CSS *Hudson* in the Beaufort Sea and associated research; resurveys and revisory surveys for the continuing charting program on the Pacific coast; further studies in vessel positioning conducted by the Navigation Group; and a market analysis to determine market potential for Pacific Region charts and user requirements.

Final design modifications were completed for the CSS *Wm. J. Stewart* replacement vessel and a contract for construction is expected in 1982. Construction of survey launches for this vessel was initiated during the year and delivery is expected in 1982.

The Regional Director of Hydrography acted as a consultant to the Government of Ireland, studying the requirement and feasibility of establishing an Irish Hydrographic Service. His report was submitted in April and is now being reviewed by the appropriate Irish authorities.

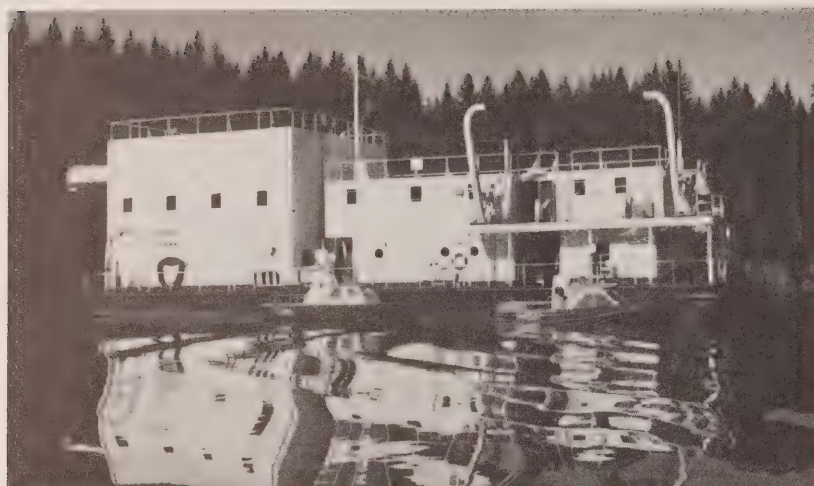
Field Hydrography



The Field Hydrography Section is responsible for conducting hydrographic surveys of B.C. coastal, western Arctic, and navigable inland waters of the Pacific Region, in order to ensure that requirements for navigational information are met. Alterations of, and additions to, traffic routes, types and sizes of vessels, harbours, bottom topography and coastlines — all require an ongoing survey and resurvey program.

The barge *Pender* was again assigned to hydrographic field surveys for a two month period in 1981. A large scale chart will be produced using the information gathered during the 1981 Okisollo Channel survey. After this project was completed, the survey party moved to Vancouver Harbour on assignment for the Ministry of Transport. A survey of Skidegate Inlet and approaches, previously surveyed by the British Admiralty in 1911 was begun with logistical support being provided by CSS *Richardson*. The final survey of the year for this party was undertaken in Campbell River where two field sheets, at a large scale, were completed by the end of the season. (Contact: B.M. Lusk.)

CSS *Richardson* also provided support for a survey party in Port Neville, Chatham Channel; these were resurveys of areas originally done in the 1920s. A revisory survey was also carried out from the *Richardson*



*Barge Pender and
launches in Okisollo Channel
(Octopus Islands)*

in Jervis Inlet where some further data was required to update a previous survey. Later in the season large scale surveys of a newly-dredged area in Nanaimo Harbour was carried out at the request of the Ministry of Transport and a wharf in Esquimalt Harbour was resurveyed at the request of the Department of National Defence. (Contact: J.V. Crowley.)

In mid-September the region's Navigation Group carried out further monitoring of the Loran C patterns in the southern Vancouver Island area. These investigations will supply correct time delays and more accurate propagation information for new, latticed charts in southern areas. Early in the year, this same group carried out Accufix-Loran C investigations in the western Arctic to assist further navigation. (Contact: A.R. Mortimer.)

CSS *Hudson*, equipped with five survey launches left Victoria on July 6 for the western Arctic. A large-scale, fully automated hydrographic survey of a 10 mile wide, 170 mile long shipping corridor, through the area of the Beaufort Sea known to contain Pingo-Like Features (PLFs), was commenced on July 17. The survey launches ran in shifts for 16 hours per day collecting soundings on parallel lines 100 metres apart while *Hudson* swept the area with side-scan sonar. Despite poor weather, 52% of the corridor was completed before *Hudson* departed from the Beaufort Sea on September 4. The remainder of the season was spent conducting a multidisciplinary survey in Lancaster Sound. (Contact: A.D. O'Connor.)

Revisory surveys of Victoria, Vancouver and Nanaimo harbours and the Strait of Georgia from Victoria to Port Hardy were also carried out.

Sailing Directions

The eighth edition of the *British Columbia Coast Sailing Directions* (North



ARGO positioning system tower erected by survey personnel in the western Arctic



Four of the survey launches that gathered sounding information in the Beaufort Sea (Hudson 81)

Portion), Volume II, was published in May. This edition includes new information on vessel traffic management, tidal streams, ports, Loran C, seabed, search and rescue, and regulations. Volume I, (Southern Portion), and Volume II are published in alternate years.

The fifth edition of *Small Craft Guide, Volume I, Port Alberni to Campbell River including the Gulf Islands*, was also published in May. This publication contains extensive revisions concerning passages in the Gulf Islands. A new edition of the companion, *Volume II, Boundary Bay to Cortes Island*, will be published in 1982.

Helicopter photography operations and revisory surveys were carried out to improve and update these publications.

Hydrographic Development

A new PDP-11/34 based computer system and peripherals were acquired early in the year. Current sounding selection software running on the PDP-8 computers was transferred to the new computer. All existing programs were adapted for compatability with the new plotter and a program was written which allows quick and accurate verification and editing of selected sounding points using a graphics terminal.

In July, the complete package was installed on CSS *Hudson* for the Beaufort Sea survey program. During the Arctic surveys, two eight hour processing shifts were required daily to keep up with the volume of data produced. Typically, sounding plots were produced for four launches

within four hours of their return to *Hudson*.

The system performed admirably throughout the survey. Several software "bugs" were identified and corrected.

Final plotting of the data was delayed due to unanticipated problems with the plotting program caused by both the immense quantity of the input data, and by the extreme scale change requested. Although corrective action was taken to produce this year's plots, a major rewrite of this software is indicated.

Chart Production and Distribution



The regional Chart Production and Distribution Section is responsible for the processing of all survey and other data into new charts and publications and for the timely distribution to dealers, and directly to users.

Twelve new Pacific region charts were produced in 1981; nine by the region and three by headquarters. In addition, 42 new editions (including one by headquarters), 34 reprints (12 by headquarters), three overprints, eight patches, and 110 Notices to Mariners were completed.

The first two charts, L/C 3606 Juan de Fuca Strait and 7686 Police Point and approaches (N.W.T.), were produced completely utilizing automated systems.

Continuing the transition to metric format, the 1:40,000 series from Victoria to Nanaimo were completed along with four 1:50,000 series for the west coast of Vancouver Island.

Ministry of Transport (MOT) ships' masters participated in a meeting at the Institute concerning the updating of charts for the western Arctic. A meeting, hosted by the chart production staff, regarding the surveying and charting of the Fraser River, was attended by MOT, Navigable Waters Protection Act and Department of Public Works personnel.

Several major developments in Automated Cartography occurred in 1981. The new custom-made digitizing system was delivered; this included a more accurate table, a special hydrographic cursor for digitizing soundings, and a swivel cursor to enable smooth digitizing of continuous lines.

Computer software underwent extensive changes including implementation of the Digital Data Library (DDL) on the Univac 1100/60.

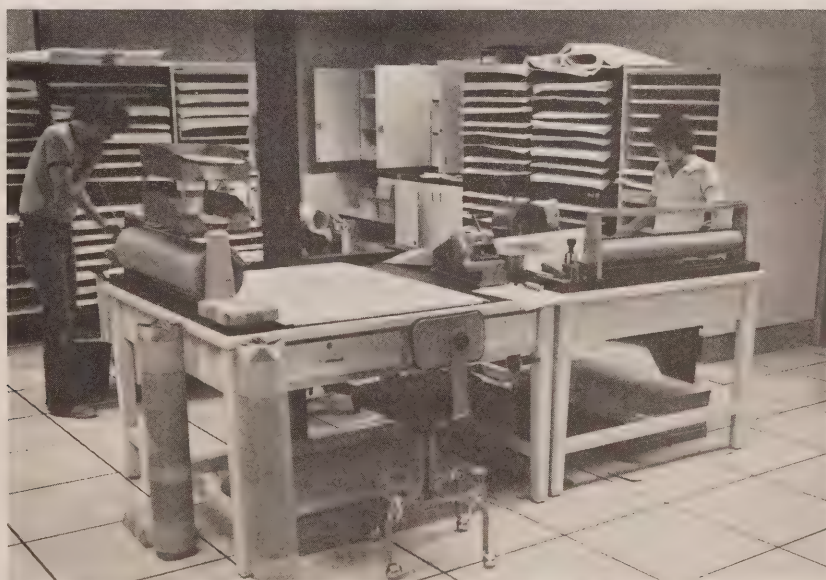
The DDL will enable Pacific Region to archive graphic files on magnetic tape for long term storage.

The demand for graphic and other information from the Technical Records group continued to increase during 1981; up 61% over the previous year. Similarly, requests for information to update Sailing Directions and Small Craft Guides increased 21%. The number of MAREP reports (the Canadian Power Squadron's Marine Reporting Program) fell to 262, compared to 450 in 1980.

The move towards cyclical printing for most charts, started in 1978, has now begun to show good results. Hand amendments have been reduced by 35% despite an increase in chart sales. This has allowed a considerable cost saving in just three years and has also reduced the amount of wastage of cancelled stock by 70%. In 1981, a total of 1,348,585 hand amendments were made to 163,437 charts.

A market analysis survey conducted during the summer months elicited user compliments and criticisms about Pacific region's charts and publications. As a direct result of the analysis, a system of advance ordering will be implemented for the 1982 tide tables.

In 1981 there were two editions of the Chart Dealers Newsletter and six press releases issued. There were 45 chart dealership inspections, 28 new dealerships approved, 28 withdrawn, and 12 new Small Craft Guide dealerships approved. During the year, Pacific region distributed 203,913 charts, 78,687 publications and 22,318 catalogues and other free publications.



*Wrapping area in
chart distribution centre*

Tidal and Current Surveys

This program provides tidal, current and water level data, along with other information and expertise, for the Canadian west coast and western Arctic. A network of permanent and temporary tidal gauges is maintained for operational and research purposes.

The task of analysing 175 data records from current meters and bottom-mounted pressure gauges, obtained during the Coastal Ocean Dynamics Experiment (CODE) off the west coast of Vancouver Island, continued. Large diurnal currents have been found on the shelf north of Juan de Fuca Strait. These currents can be attributed to continental shelf waves, driven by the diurnal tide. (Contact: W. Crawford and W.S. Huggett.)

A current meter installed at Race Rocks in the Strait of Juan de Fuca was recovered after one year of operation. Records have been analysed and current velocity predictions for Race Passage have been made. (Contact: M.J. Woodward.)

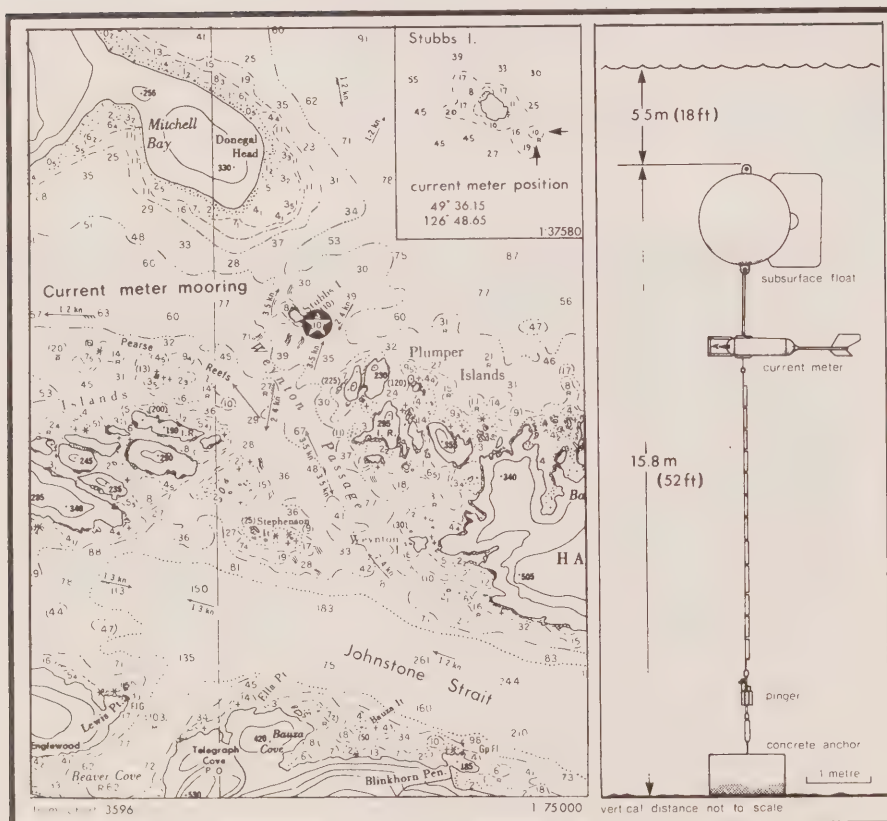


Chart showing Stubb's Islands location of current meter and its description

Work on the inclusion of the salt wedge into the Fraser River tidal model continued. Many field observations were carried out to verify this model. (*Contact: A.B. Ages.*)

Data collection and tide graph processing from temporary and permanent tide gauges continued. In the western Arctic temporary gauges were operated at four to eight week periods at Garry Island, Atkinson Point, Cape Dalhousie and Baillie Island. For the second year, gauges at Gold River, Tahsis and Zeballos were operated for a cooperative project with Pacific Geoscience Centre (PGC) to determine tilting of Vancouver Island. (*Contact: F.E. Stephenson.*)

Diving Unit

During 1981, 123 dives were made on the Pacific coast and in the western Arctic in support of the oceanographic and hydrographic work of the Institute.

In particular, for the Hydrographic Division, several tide gauges were installed, inspected and/or serviced. Studies of seiches were carried out in Juan de Fuca Strait and Haro Strait for Ocean Physics Division and the Pacific Geoscience Centre. (*Contact: F.E. Stephenson.*)



Tsunamis

A historical study of all tsunamis recorded on Canada's west coast ports is in progress, and has provided a basis for determining how frequently destructive waves may be expected. Primary evidence of past events is obtained from the tide records of permanent gauging stations. Other sources, such as newspaper accounts and diaries are being explored for information about those events that have been experienced before tide stations were operating. The waves from Japan's great Sanriku tsunami of June 15, 1896 are of particular interest.

Results of the tsunami frequency studies are being used by consulting engineers in investigating proposed sites for liquid natural gas terminals, and by planners in making recommendations for land use options in low lying coastal areas.

Active co-operation is being extended by the IOS Tsunami Unit to the International Tsunami Warning System. Effort is being directed towards increased automation of tsunami detection and communications, so that the earliest possible warning can be provided to all threatened coasts in the Pacific when potentially destructive waves occur. A concept of regional warning systems is being developed for the southern Pacific as a possible means of improving response times. The B.C. Earthquake and Tsunami Working Group is continuing to upgrade its procedures for public warning and possible evacuation. Within the Canadian Hydrographic Service techniques have been developed for surveying wave runup and post-tsunami damage.

Research is beginning on submarine landslides as a possible source of tsunamis that may impact on Canadian coasts. Evidence of past occurrences is being collected. (*Contact: S. Wigen.*)

Engineering Services



Engineering Services provides electronics and mechanical engineering and technical support to the research, surveys and ship operations. The Division also provides the industrial liaison, contract support and special programs interface for the Institute.

Electronic Engineering Development

Major electronics projects in 1981 focussed on *Hudson 81* preparations, acoustic engineering support, and long-term developments for Arctic hydrography.

Development, coordination, and implementation of a PDP-11 based

field data processing system for hydrography, development and implementation of a navigation module to permit straight-line steering, and a GPIB/SAIL/RS232 (real time data provision system) interface for PHAS (portable hydrographic acquisition system) to accommodate the new ARGO positioning system were accomplished for the *Hudson* expedition.

A new 200 kHz, one-degree beamwidth transducer was specified, acquired, and implemented into the system for the acoustic doppler current measurement project. Numerous modifications were made to the doppler system to improve sensitivity and signal-to-noise ratio. A sonar and doppler recording system for oilwell blow-out studies was designed and implemented and a contract for an acoustic positioning system for the submersible *Pisces* was supervised.

Long-range projects in support of Arctic hydrography, funded through the High Arctic Research Program (HARP), included continued development of a launch autopilot system, a contract to grey-scale depths as an alternative to numbers and contours, and a system for the computerized deployment of survey launches.

Numerous other electronics projects for various IOS groups were pursued. These included a plankton counting and sizing system, a new datalogging system, a five-channel frequency counter, a microprocessor-based Aanderaa-format data translator, a partial pressure carbon dioxide (pCO₂) microcontroller, and continuing SAIL development. (*Contact: T. Curran.*)

Mechanical Support

Mechanical design and fabrication projects included mounting brackets for acoustic and optical transducers, a cooling jacket for column chromatography, a sediment trap and a transparent air separator. (*Contact: T. Curran.*)

Institute Electronics

Preparations for the *Hudson* cruise involved extensive modifications to existing equipment, trials of new equipment, and the outfitting of five survey launches.

In addition, staff were trained in the maintenance of the new ARGO positioning system, the PDP-11/34 processing system, the new depth sounders and digitizers, and the complex navigation and interface modifications to the PHAS.

All preparation work, including test, installation of equipment and spares, and training of personnel, was designed to ensure continuity of the survey. Three technologists were assigned to the *Hudson* cruise; two

on the ship and one at Tuktoyaktuk to service the ARGO positioning system. (*Contact: R. Taylor.*)

Industrial Liaison and Contracting

The Institute of Ocean Sciences has a policy of conducting a significant portion of its program through private sector contracts. The fostering of government/industry assistance in the marine industries is pursued via the D.S.S. Unsolicited Proposal Program and the Program for Industry/Laboratory Participation (PILP). Liaison and support in these areas is provided by Engineering Services. During the 1981-82 fiscal year the total level of science contracts, exclusive of ship charters, exceeded \$2.6 million. Two PILP proposals were initiated during 1981-82 in response to IOS technology transfer efforts, and although neither of these has yet to result in a contract, both are still active. IOS will continue to pursue a very active role in technology transfer programs over the next few years. (*Contact: J.V. Watt.*)

Oceanography

The IOS oceanography program comprises research in physics, chemistry and ecology. Knowledge and understanding of ocean processes, marine life, and environmental quality are pursued to meet the challenge of existing and potential problems regarding industrial development in nearshore and offshore areas, climate, navigation, and marine resource management and development.

Dissemination of research results is generally undertaken through the open literature and, high on the list of IOS priorities, is the active encouragement of technology transfer between the private and public sectors.

Major achievements during 1981 included good progress on CODE (Coastal Ocean Dynamics Experiment) data recovery and analysis, extensive Arctic data compilation and review, CO₂ studies as part of the Hudson 81 research cruise, preparatory work for the major N.W. Passage field program in 1982, and the successful completion of toxicology studies.

In addition, program plans were altered to contribute to the Fisheries and Oceans mine tailings monitoring program in Alice Arm and vicinity. This work covered daily surveys of salinity, temperature and turbidity, and water samples. IOS will continue next year to use the Alice Arm/Observatory Inlet area as a study site to carry out ongoing coastal research as it relates to the deposition of tailings.

Ocean Physics



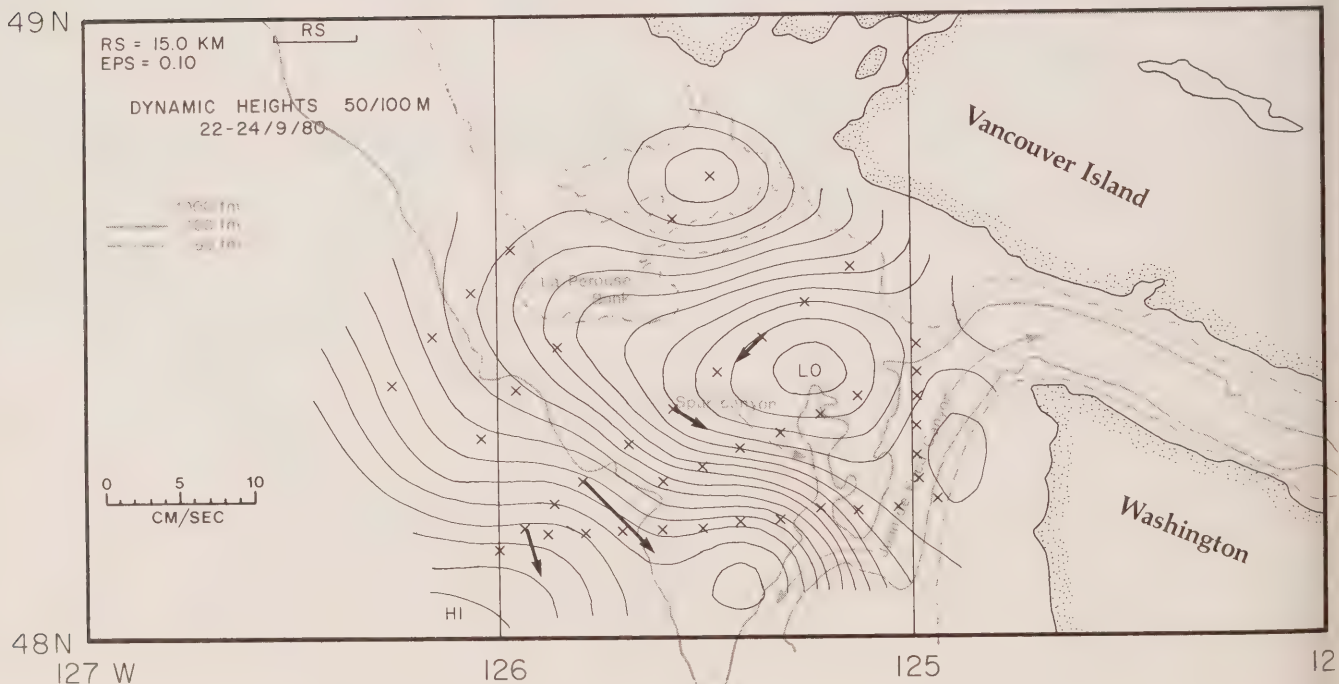
The Ocean Physics program is designed to increase the understanding of physical properties, processes, and phenomena in Canada's Pacific Ocean and in the western Arctic. Nearshore, and coastal area estuarine research is required to respond to water and land use issues. Offshore, deep-ocean and Arctic studies will have influence on the course of industrial development. With air-sea interactions included, the total physical oceanography thrust will move further forward to reliable prediction in areas of environmental quality, renewable and non-renewable resource development, climate and navigation.

Highlights during 1981 included the confirmation of the salt-fingering process (ocean mixing transferring heat and salt at different rates), the compilation of the final data from the weatherships, completed analysis of the 1977 Queen Charlotte Sound CTD (current, temperature, depth) data, and the corroboration of suspected anomalies in tidal records for M'Clure Strait and Viscount Melville Channel through numerical modelling work.

Coastal Zone Oceanography

The major aim of the Coastal Zone Oceanography program is to advance the understanding of the dynamics of coastal processes, mixing, the circulation of estuaries and of the exchanges between shelf and inshore waters. Phenomena investigated include: upwelling, coastal currents, tidal mixing, the interaction of tidal flows with topography and the circulation that this type of interaction induces. This year the Ocean Mixing section was amalgamated with Coastal Zone Oceanography to facilitate, with instrumentation currently under development, the pursuit of mixing processes in inshore and coastal waters. Studies on microstructure, salt-fingering and other mixing processes in the deep ocean continued.

Dynamic height contours between 50m and 100m for a cruise in late summer 1980. The contours show the presence of a large eddy off Vancouver Island. The gradient of dynamic height yields current shear between 50m and 100m. The shear vectors are plotted and the agreement indicates substantial geostrophy in the field. The overlay shows the relationship to the bottom topography. The northern end of the spur canyon always seems to lie at the centre of the eddy suggesting some dynamical relationship.



Continental Shelf Studies

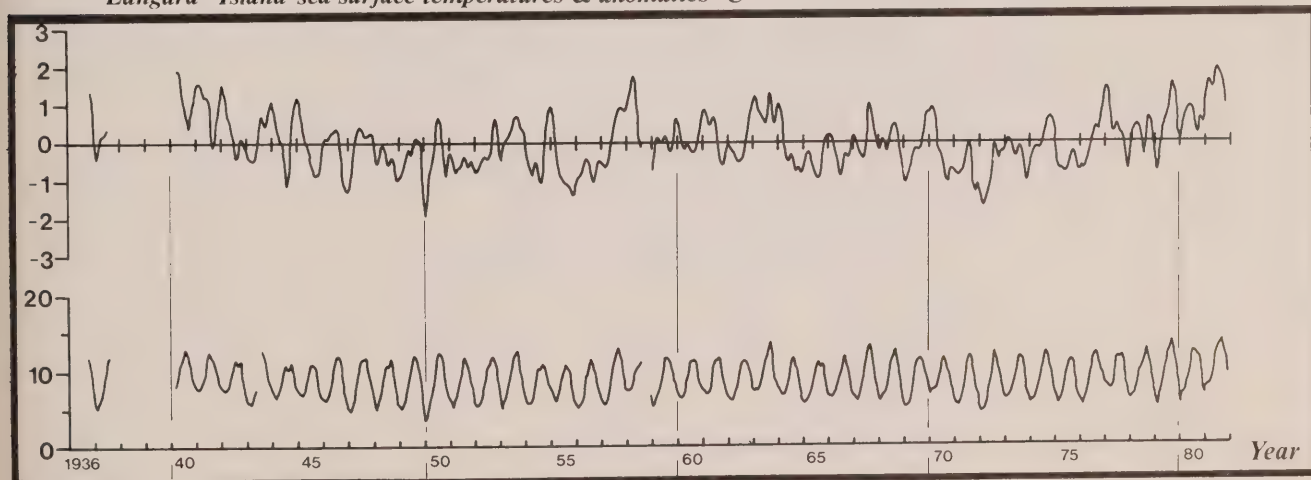
The Coastal Ocean Dynamics Experiment (CODE) 3-year field phase ended in June 1981. The overall data recovery from moorings was 93%. The final survey of hydrographic conditions indicated that the low oxygen anomaly was developing once again reflecting 1980 conditions almost exactly despite a substantial difference in the ambient weather conditions.

An overview of the physical oceanography of the southern Vancouver Island continental shelf and a theory of upwelling controlled by the local topography has now been developed. (Contact: H.J. Freeland.)

A line of five moorings was deployed along the shelf-edge from southern Vancouver Island to the Queen Charlotte Island in support of an international venture called SUPERCODE. The purpose of the experiment is to search for low frequency disturbances propagating from the tropics along the shelf wave-guide. C.I.C.E.S.E. (Ensenada, Mexico) has deployed moorings off Baja, California and scientists from Oregon State University have deployed moorings along the U.S. coast. Preliminary examination of data indicates substantial coherence between currents off Crescent City (northern California) and off southern Vancouver Island. However, the coherence appears to be largely lost between sites off northern and southern Vancouver Island. (Contact: H.J. Freeland and D.M. Farmer.)

Time series of mean monthly sea surface temperature (SST) measured at the Langara Island light station for 45 years, lower plot. The dominant signal is the annual cycle. After removing the annual signal we plot the anomaly of SST, upper plot. The high positive anomaly observed in June 1981 was the largest one measured since observations began in 1936; temperatures reached a maximum of 2.3°C above normal.

Langara Island sea surface temperatures & anomalies °C



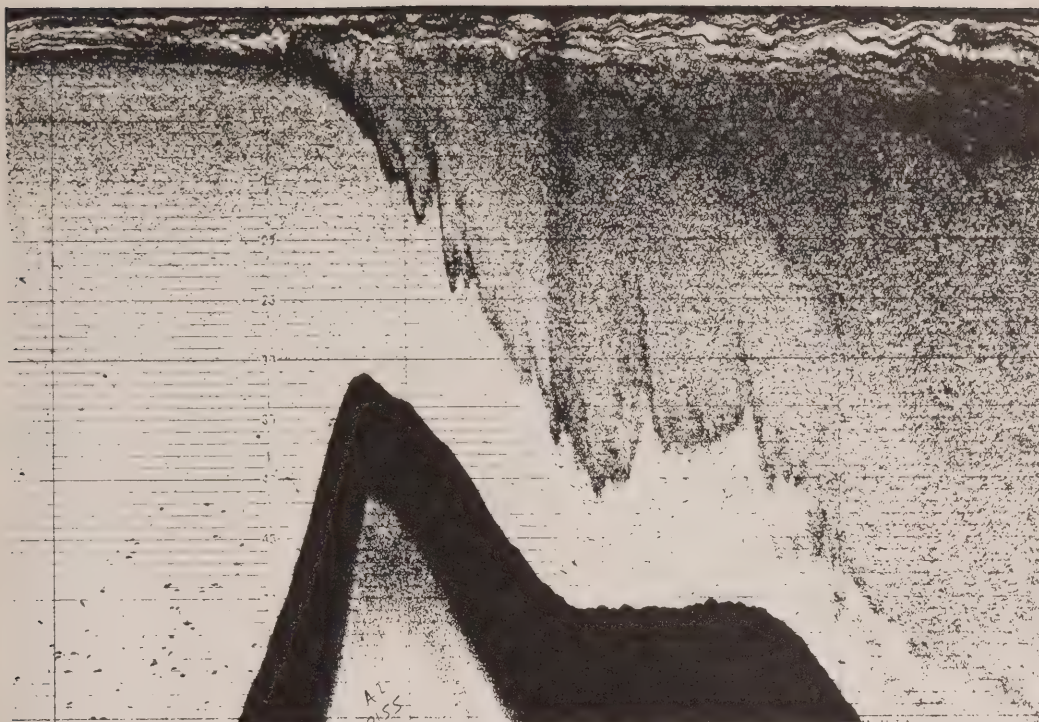
One mooring location is common to CODE and SUPERCODE. This mooring is to be maintained for up to 5 years to acquire some data on the variability of major current systems. For example, a spectacular reversal of the dominant current systems occurs each spring, called the spring transition. The objective is to determine, with 5 or more years of data, whether this is a locally driven event or remotely forced (responding to major changes in weather systems at large distances). Preliminary data indicate that the latter is more likely. (*Contact: H.J. Freeland.*)

Fjord Studies

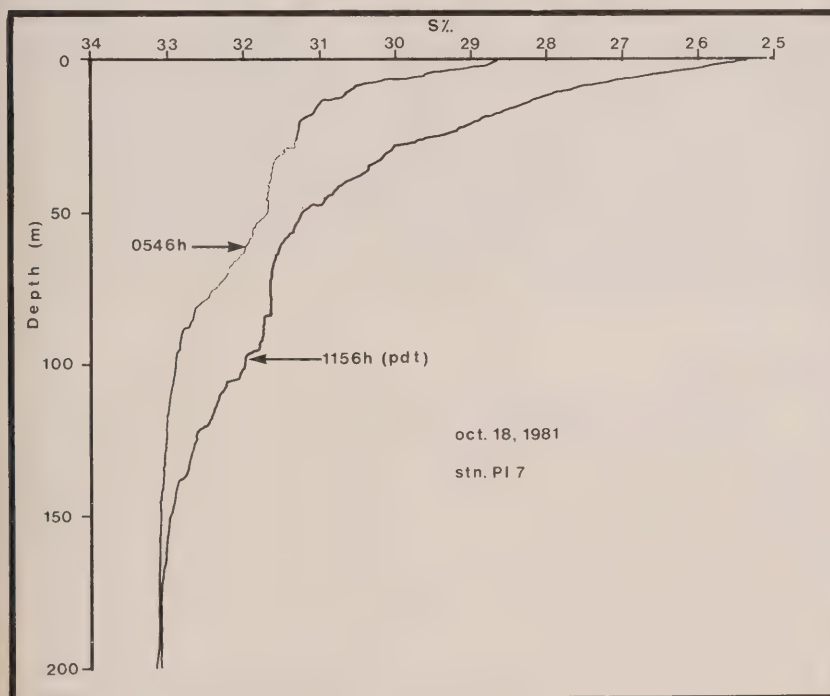
Density data, tide gauge records, anemometer and river discharge data provided a basis for examining the internal pressure field in Knight Inlet. The results emphasized that almost all of the density field adjustment occurs in the top few metres. Significant seasonal fluctuations were observed showing that in summer the main balance of forces in the surface layer was between the horizontal pressure gradient and horizontal stress associated with strong up-inlet winds, with convective accelerations playing a much smaller role than had been supposed. During low run-off periods the horizontal pressure gradient almost disappears, or even changes sign.

Analysis of energetic processes near the sill of Knight Inlet continued by means of a field study combining Aanderaa current meters, automatic current profilers (contributed by Dr. Pond, U.B.C.) and a range-gated Doppler sonar. These measurements have provided a much more detailed data base of documentation than previously available and become the basis for systematic modelling of these flows which occur not only in Knight Inlet, but in many fjords along the coast. (*Contact: D.M. Farmer.*)

A program to study the circulation of Alice Arm together with the adjacent waters of Observatory Inlet and Hastings Arm was undertaken following expressed concern about the discharge of mine tailings. A second but related effort was directed at monitoring the physical properties, including turbidity, in Alice Arm. Preliminary studies show that flows over submarine sills in the area, which play a prominent part in controlling the circulation, exhibit many of the features previously studied in detail in Knight Inlet. Acoustically-derived images show water moving under the influence of the tide over the crest of the sill in Observatory Inlet, diving down to considerable depths. Salinity and temperature profiles obtained 4 miles east and west of the sill show substantial changes in water properties over a few hours indicating modification of the water down to nearly 200 metres. These energetic processes undoubtedly affect exchanges into Observatory Inlet and Alice Arm. An array of current meters, tide gauges, thermistor chains and

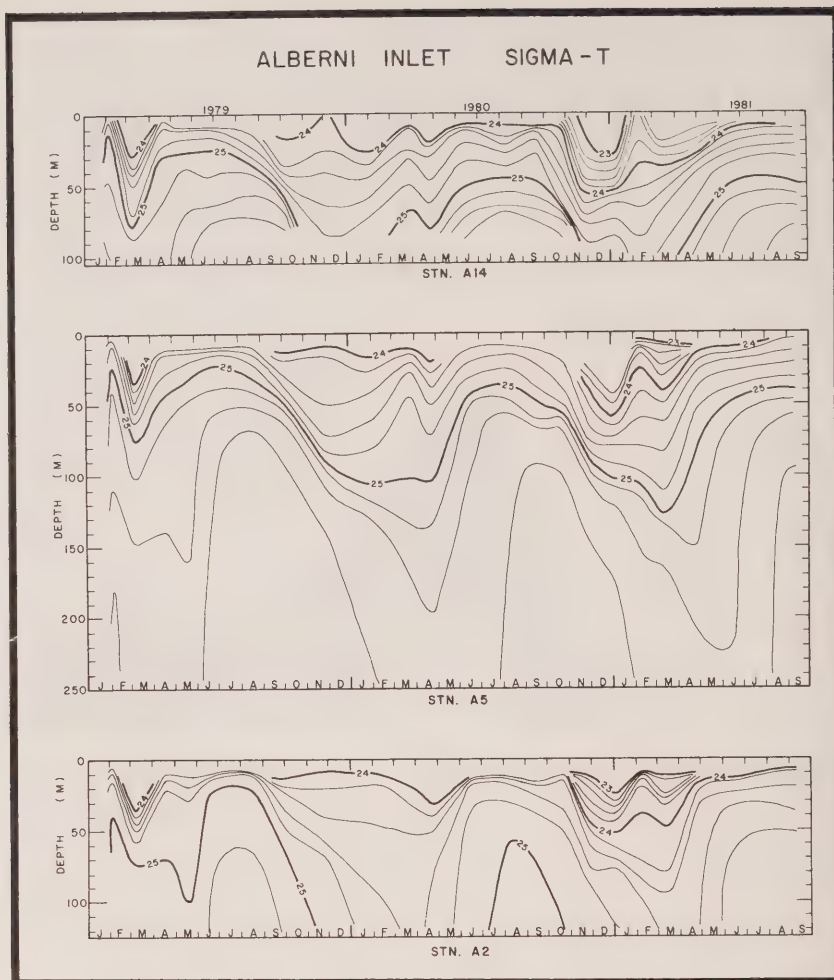


Acoustically derived image showing the Observatory Inlet sill during an ebb tide. The ragged boundary between salty water (below) and brackish water is clearly visible. The brackish layer greatly deepens near the sill and is mixed with the salty water.

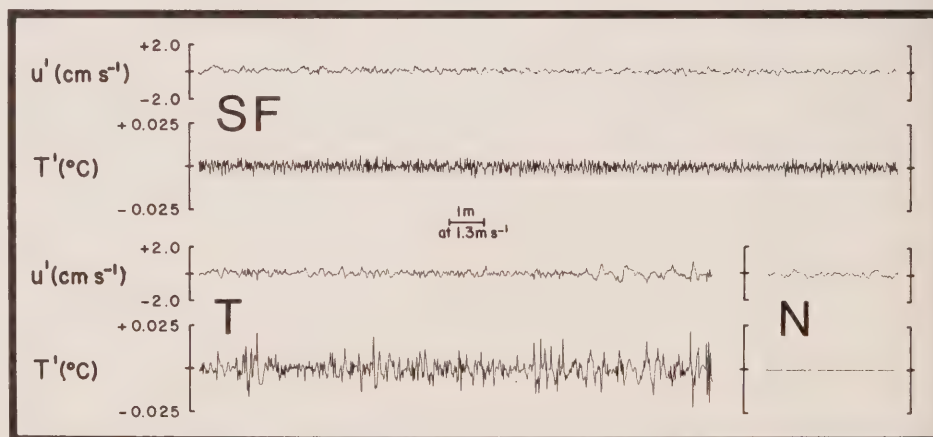


Two profiles of salinity ($S_{\text{‰}}$) recently obtained 4 nautical miles west of the Observatory Inlet sill near the Nass River, demonstrate the rapid changes that can occur over a few hours through the water column. The changes occur through energetic interaction between tidal currents and the sill which results in the submergence of fresh surface water, partly derived from the Nass, accompanied by intense mixing. The mechanism is illustrated in the acoustic image.

The figure shows specific density anomaly vs time for 3 locations in the Alberni Inlet system. Stn. A2 is in the inner basin, Stn. A5 is in the outer basin, and Stn. A14 is in Barkley Sound. The annual cycle of density changes is readily apparent.



Traces of fluctuating temperature T^1 measured by a constant depth system towed east of Hawaii reveal the difference between signatures of two different microscale mixing processes. Salt fingers (SF) are characterized by signals of very limited amplitude and wavelength, which contrast sharply with the much more random fluctuations associated with three-dimensional turbulence (T). A noise level signal (N) is included for comparison.



anemometers have been installed in the area and extensive ship surveys are planned for 1982. (*Contact: D.M. Farmer and D.J. Stucchi.*)

The investigation of some oceanographic features of the Alberni Inlet-Barkley Sound fjord system, and the influence of continental shelf processes on the system continued through 1981. Data analysis is proceeding and a synthesis is emerging. The data confirm that a complete annual replacement of the water in the system occurs with a decrease in dissolved oxygen content, after an initial increase, as dense water flows into the fjord. The data suggest that upwelling processes on the continental shelf supply the low oxygen, high density water allowing renewal of the deep water in the fjord. (*Contact: D.J. Stucchi and W.H. Bell.*)

Acoustic Remote Sensing

The range-gated Doppler sonar under development was tested with a new, narrow beam transducer. Encouraging results were obtained in Knight Inlet, where a number of comparison measurements were taken in a sequence of runs over the sill in conjunction with moored current meter observations. After correction for ship motion, the high flow speeds in the neighbourhood of the sill crest, associated with lee waves and related phenomena, are clearly seen in the velocity maps. The technique promises to be a powerful tool for studying tidal flows and related coastal processes.

Work was begun on development of a correlation sonar for remote measurement of velocity in the ocean. Data were collected with the range-gated Doppler system, reconfigured as a single-channel correlation sonar. Results have provided estimates of the correlation function used in a preliminary analysis of the correlation technique as applied to remote velocity profiling. Another project underway is designed to test the concept of remotely sensing wind-speed through ambient noise measurements in the environment of the continental shelf.

(*Contact: D.M. Farmer.*)

Ocean Mixing Processes

Ocean mixing studies have continued with the exploration of the small-scale processes which operate in the ocean. During the year, analysis of towed temperature signals from the subtropical gyre of the north Pacific has revealed signatures which are contrasted with the much more random fluctuations typical of three-dimensional turbulence. Wide-spread occurrence of salt fingers in subtropical thermoclines has long been hypothesized; now that they have been observed directly, standard theories of ocean mixing must be adapted to allow for the fact that salt fingers, unlike ordinary turbulence, do not transfer heat and salt at the same rate. (*Contact: A. Gargett.*)

Wind Mixing and Restratification

Analysis of temperature observations in Babine Lake confirmed that the depth of wind mixing decreases and that density stratification forms beneath the retreating mixing zone when the stabilizing effect of the cooling below the temperature of maximum density ($\sim 4^{\circ}\text{C}$) dominates, providing estimates of the efficiency of wind mixing under these special conditions. The observations also showed that density gradients increase in the surface boundary flow as the depth of mixing decreases and that the process accelerates in the final stages as the surface buoyancy flux due to cooling is distributed over a progressively thinner layer. (*Contact: D.M. Farmer.*)

Lighthouse Station Program, Task Forces, Mooring Technology

The surface-seawater sampling program at 19 British Columbia shore stations was continued. Pronounced warming of surface waters occurred along the coast in 1981. A large positive sea-surface temperature anomaly, 2.3°C , seen at Langara Island was the largest ever recorded at that site since the program was started in 1936.

Emphasis was placed on the processing and publishing of historical data including those from Bamfield Marine Station and Cape Beale Lighthouse, the West Vancouver Laboratory, and the Vancouver Public Aquarium.

Assistance was provided throughout the year to government departments and the private sector on a variety of environmental problems. (*Contact: L.F. Giovando.*)

A watching brief was continued on developments in mooring technology and related aspects, such as drag and vibration problems. An investigation on the influence of turbulence on drag was initiated. Assistance with mooring design was provided to other groups in the Institute. (*Contact: W.H. Bell.*)

Frozen Sea Research

The objective of the frozen sea research program is to advance the knowledge of the circulation, heat budget and dynamics of the Arctic Ocean and to provide expert information and advice to industry, government agencies and the public.

Eurasian Basin Survey

A survey of the Eurasian Basin known as EUBEX and planned as a cooperative endeavour with the University of Washington, was carried out in a modified form during March and April. The extent of the survey was drastically curtailed by failure to obtain clearance to enter U.S.S.R. airspace east of 32°E and by the loss of the aircraft operated by the University of Washington. Nevertheless an airborne CTD survey covering the area of the ice edge north of Spitsbergen to 85° 30'N and from the Greenwich meridian to 32°E was carried out from Longyerbyen and the FRAM III ice camp. These measurements showed detailed features of the Atlantic water entering the Arctic Ocean and its cooling as it travels along the shelf break north of Spitsbergen. This current is the main source of inflow into the Arctic Ocean and has an effect on the entire basin. Preliminary processing has shown that the data set is of good quality and interpretive work is underway. (Contact: E.L. Lewis.)

Deployment of a current-meter mooring from moving sea ice. The mooring winch is on the right, and the ice plug from the mooring hole can be seen to the left of the hanging current meter. The mooring has been "stopped off" at the bar lying across the hole to enable insertion of the current meter into the mooring string.



Beaufort Sea Oceanography

An observational program conducted in the Beaufort Sea during March and April included the installation of current meters which were recovered in August. Observations were made west of the U.S. border in cooperation with the U.S. Coast Guard. The entire survey formed part of the second Beaufort Sea Winter Ice Experiment with other components

being undertaken by Dome Petroleum and the Atmospheric Environment Service of DOE. CTD sections were taken extending from the deep basin waters to the edge of the landfast ice over a 750 km stretch of coastline. In all, 60 CTD profiles were acquired and seven moorings were deployed and recovered. Measurements verified the presence of a westward current jet overlying the continental slope and demonstrated the existence of a thermohaline front on the outer shelf marking the boundary between waters of the Canadian basin and a mass of saline water at its freezing point, originating from ice formation over the continental shelf. The current meter moorings were situated near this front and those near the sea floor were periodically engulfed by this cold, saline flow. Analysis of these data is proceeding with particular attention being paid to propagation of the front and cross-frontal mixing. (*Contact: H. Melling.*)

Polynya Experiment

Data reduction from the Polynya Experiment is now essentially complete and presentations were made of preliminary analyses at the 1981 Canadian Meteorological and Oceanographic Society (CMOS) meeting and the autumn meeting of the American Geophysical Union (AGU). The measurements of eddy heat flux made within the growing (atmospheric) convective boundary layer show good agreement with existing data taken elsewhere under strongly advective conditions on much larger physical scales. The oceanographic measurements indicate a source of sensible heat in the form of warmer water brought to the surface during high-current periods of the tidal cycle. The existence of the polynya depends on the balance between this oceanic heat source, the surface heat loss, and mechanical removal of ice during periods of high current. (*Contact: E.L. Lewis and R.A. Lake.*)

Northwest Passage

The anticipated year-round use of the Northwest Passage by ice-breaking tankers has stimulated a major research effort in that area. The Working Group on Northwest Passage Oceanography, chaired by IOS, has planned a major field program for the spring of 1982 which has involved a great deal of logistical preparation and instrument testing. Specific projects include: the Channel Flow Experiment (Prince of Wales Strait), the Physical Oceanography of M'Clure Strait and Western Viscount Melville Sound, and a synoptic CTD Survey of the Arctic Channels. The last project will be conducted by contract. These projects are being carried out in association with those of the Canadian Hydrographic Service at both IOS and the Canadian Centre for Inland Waters (CCIW), and with the Barrow Strait Project undertaken by the Physical Oceanographic Group at the Bayfield Laboratory. A

complementary survey may be undertaken by Arctic industry in the Northwest Passage and it is intended that data from all these operations will be amalgamated. (*Contact: R.A. Lake.*)

Oil Well Blowout Studies

Work proceeded on deep oil well blowout studies. The results of laboratory measurements on gas hydrate formation in rising gas bubbles have been incorporated into a mathematical model of a complete bubble plume. This should enable calculation of the water depth at which hydrate formation removes completely the buoyancy normally associated with a rising plume of gas bubbles. An international cooperative study concerned with the subsea containment and control of oil well blowouts will be undertaken in 1982 at the Massachusetts Institute of Technology. IOS currently performs an advisory function and will be involved in the field tests. In addition IOS is represented on the management committee of the Arctic Marine Oilspill Programme, chaired by EPS, and on the technical committee for the Cape Hatt Oilspill Experiment. (*Contact: D. Topham.*)

Technical Development

A theoretical analysis of the transient response of a cylindrical conductivity cell was carried out. This enabled development of a computer simulation of the effect of the CTD instrument's response to high conductivity gradients in the sea. The results were expressed in terms of non-dimensional variables which took into account differing lowering rates and cell dimensions. The theory shows good agreement with available experimental results although the latter are few in number.

An airborne CTD survey system suitable for use in Twin Otter aircraft was developed for the EUBEX and Beaufort Sea surveys. It has proven very successful. Also developed was a CTD system designed for use from a Bell Model 206 or equivalent helicopter with the lightweight winch carrying only 500 m of cable. It will be utilized in the spring of 1982 in the Northwest Passage. Work was begun on the design of Mark II of the "salinity sucker," a device for measuring ice crystal content and super cooling in seawater. The device pumps seawater through a filter *in situ* and melts the collected ice. Mark II will be a "clip on" addition to the standard Guildline CTD unit commonly in use which would enable immediate experimental analysis of peculiar field observations. All these CTD systems or devices have benefitted greatly from the analysis of the design of CTD experimental programs carried out in 1980 and by studies of the transient response of conductivity cells during 1981.

A "hole melter" was designed for cutting large holes in sheets of sea ice. The principle followed that developed by the Applied Physics

Laboratory at the University of Washington. By pumping hot water from a diesel-fired boiler into a copper pipe frame which was bent to the shape of the periphery of the desired hole, a 4 kW source of heat cut an annulus of 30 cm mean radius and 10 cm thickness through 2 m of sea ice in 30 minutes. This size of hole is desirable for deployment of a current meter chain. The associated winch gear for handling loads of up to 10 kg was developed simultaneously.

The Practical Salinity Scale, 1978, has now been officially adopted by IAPSO, ICES and SCOR (International Association of Physical Science for the Oceans, International Council for Exploration of the Seas and Scientific Committee on Oceanic Research) and will be used for reporting oceanographic data. Tables of the new scale were produced for publication for UNESCO.

The group interfaced a Guildline CTD system with a transmissiometer for monitoring water quality in Alice Arm, and also supplied scientific and technical manpower to this program.

Offshore Oceanography



Offshore oceanographic studies focus on the distribution of ocean properties and currents and the processes controlling them. This includes air-sea interaction, detection of the propagation of disturbances, and the relationship between open ocean and coastal processes.

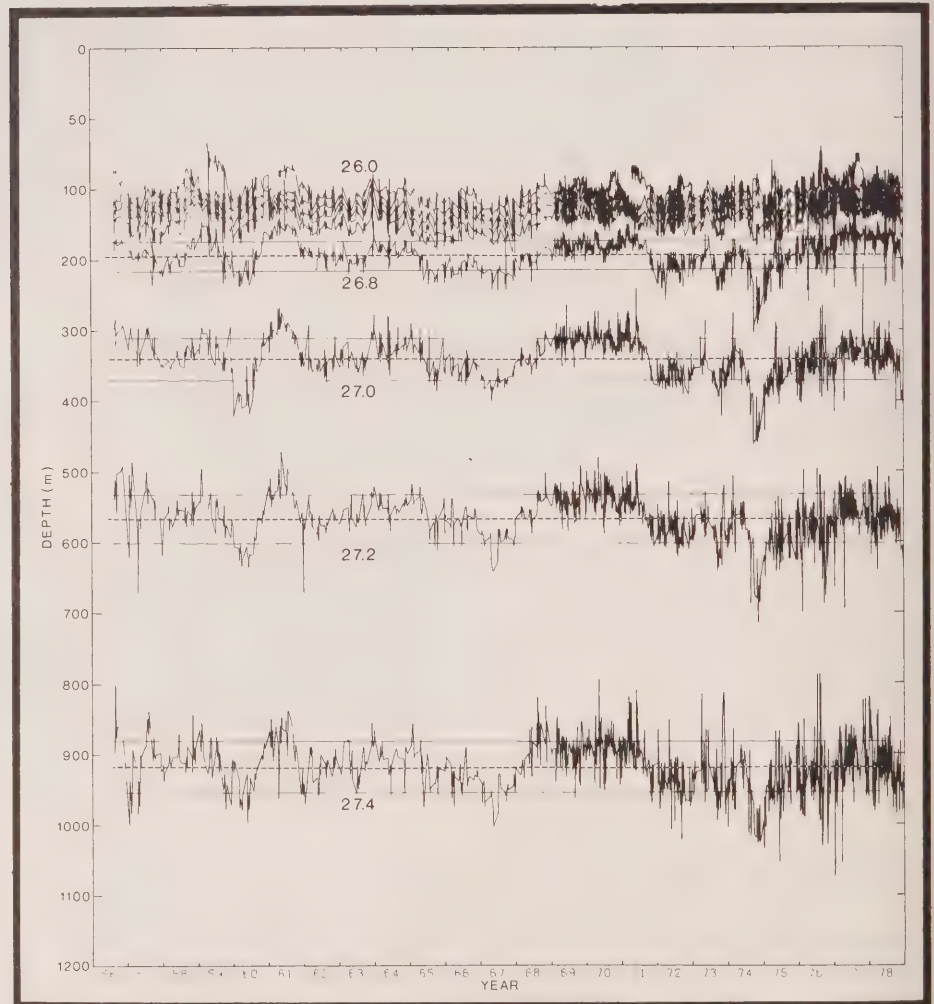
Ocean Climate Monitoring Studies

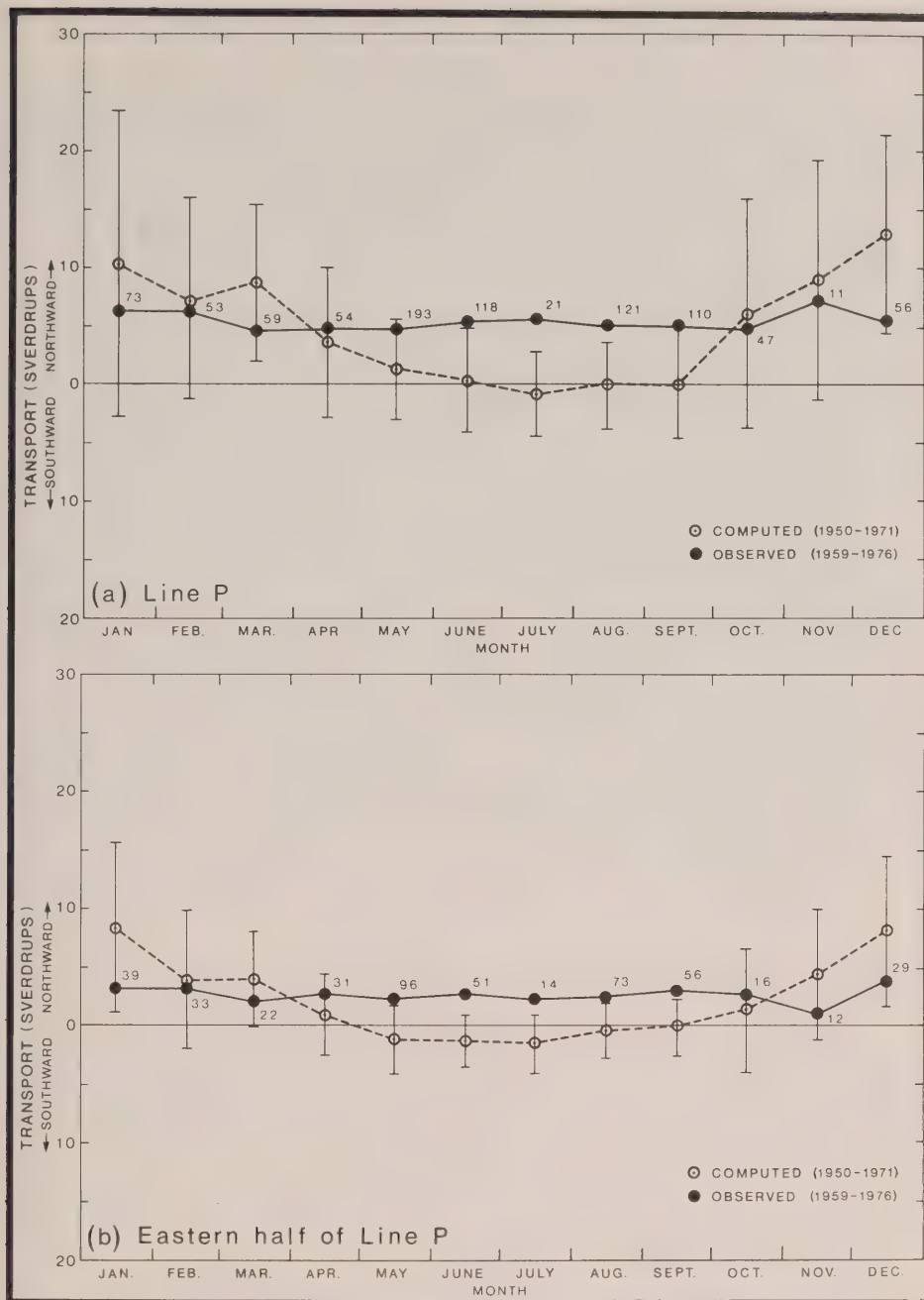
With the withdrawal of the weatherships from service in 1981, a long time-series of ocean measurements taken from these vessels at Station P and Line P came to an end. These observations very possibly constitute the longest time-series measurements in the open ocean. Such data are considered by various international agencies and most oceanographers active in climate study to be one of the most important oceanic time-series having relevance to the study of the impact of the ocean to climate.

IOS initiated a follow-on program of observations of two-weeks duration along Line P and at Station P every two months. During the oceanographic research vessel cruises in August and October, the Canadian Wildlife Service examined marine birds and several satellite-tracked drifting buoys were released near Station P on behalf of the U.S. National Centre for Atmospheric Research (NCAR). (*Contact: S. Tabata.*)

anomalies evident in the sea-surface temperatures. For example, at 200 metres, the water was relatively warm during 1956-60, with maximum temperature occurring in 1960; cool during the years 1961-71, with minimum temperature in 1965; and warm during 1972-76, with a maximum temperature in 1974. In general, the presence of warm water was associated with higher salinity and cool water with less salinity. Although there were instances when the presence of low oxygen (oxyty) water correlated with the warm water, there were occasions when the opposite occurred. Most of these water property changes at standard depths can be attributed to the effects of advection while part is explained by the long-term vertical motion of water. However, a much longer series of data is needed to determine if the long-term fluctuations have discernible periodicity. (Contact: S. Tabata.)

The depths of the isopycnal surfaces in the halocline and below do not possess any discernable annual cycle but their variability is dominated by large, long-period fluctuations. Their ranges are largest for higher values of σ_t (27.0-27.4) reaching almost 200 m and are smallest in the halocline. Their variability could not be readily related to results of any known theories of ocean circulation. Significant changes of temperature, salinity and oxyty at isobaric surfaces are related to the vertical changes of these depth for 1959 and 1961.





Observed (relative to 1000-decibar surface) and computed baroclinic transport (sverdrups) across Line P (a) and eastern half of Line P (b). The observed values are based on distribution of potential energy along the line while the computed values are based on estimates made by Bakun (private communication) using Sverdrup's model. The standard deviation associated with the observed values are typically ± 0.2 sverdrup. (Numeral denotes number of stations used to estimate observed transport. $\bar{\sigma}$ denotes standard deviation associated with computed transport.)

Coastal Ocean Dynamics Experiment (CODE)

The purpose of CODE was to provide detailed information on the spatial and temporal variability of currents, winds, sea levels and water properties off the west coast of Vancouver Island. Instrument deployment covered the period from May 1979 to September 1980.

Observations have revealed the presence of strong (10 cm/s) continental shelf wave motions of diurnal period which give rise to predominantly diurnal currents over the shelf and slope region of the Vancouver Island coast. These data provide the most convincing and comprehensive proof to date of the existence of continental shelf waves. Wavelengths are in the range 200-400 km and effects of stratification appear to be significant. A theory has been formulated to account for the generation of these waves through a time-dependent, turbulent bottom boundary layer associated with tidal currents over the shelf-slope region.

Preliminary analysis of the CODE data further reveals that wind-generated, near-inertial, internal gravity waves propagate to depths exceeding 1500 m in offshore regions but appear to be confined to near-surface depths over the shelf. There is also evidence for strong M_2 baroclinic tides seaward of the Vancouver Island shelf. Low-frequency currents, with periods of 20-60 days, have speeds in the range of 0.1-1 cm/s throughout the upper 2000 m and show considerable non-seasonable variability. Results further suggest the existence of a persistent northward baroclinic current adjacent to the coast of central Vancouver Island. Dynamic height contours reveal convoluted circulation patterns off the coast with numerous well-defined mesoscale eddies.

(Contact: R.E. Thomson.)

Queen Charlotte Sound — Hecate Strait

Analysis has been completed on much of the wind, current and water property data collected jointly with Tides and Currents section from May-September 1977 in the Queen Charlotte Sound — Hecate Strait region. Two publications deal with the strong (50 cm/s), persistent (10 days) and highly spatially-coherent, wind-generated, inertial oscillations within the seaway. Reports were completed on the currents and water properties at all locations and a summary report on aspects of the physical oceanography of the region has been initiated.

An analysis was also completed of Ekman current meter records collected in 1954 and 1955 in Queen Charlotte Sound, Hecate Strait and Dixon Entrance. Currents were predominantly of semidiurnal period and showed appreciable vertical structure at all major tidal frequencies.

(Contact: R.E. Thomson.)

Book on Oceanography

A book entitled *Oceanography of the British Columbia Coast* was published by the Scientific Information and Publications Branch in November 1981. Consisting of 291 pages, over 300 diagrams and 13 colour plates, the book deals with the physical aspects of the sea as exemplified by the Pacific Ocean and the contiguous waters of the British Columbia coast. (Contact: R.E. Thomson.)

Sea Levels in Eastern Pacific Ocean

Mean monthly sea level heights, pressures, temperatures and salinities from 16 coastal stations from southern California to the Aleutian Islands were analyzed. In addition to the pronounced annual cycle in these data, there is a significant peak centred at 5.7 years in the pressure-corrected sea level height. This signal is coherent along the entire coast and has an average northward propagation speed of 25-30 cm/s indicative of a long barotropic or baroclinic, coastally-trapped wave.

The data further show that sea level responses to atmospheric pressure fluctuations typically exceed the standard inverse barometer effect of 1.01 cm/mb. Greatest "effective" barometric correction factors are off the coasts of Washington and British Columbia where values can exceed 2.0 cm/mb; minimum values are off northern California and are less than 1.0 cm/mb. Other major features of the sea level data include significant trends: earthquake rebound times of about 10 years, pronounced barometric responses at mid-latitudes and marked correlations with sea surface temperature anomalies at low latitudes. Salinity related steric effects are shown to be important off Vancouver Island. (Contact: R.E. Thomson and S. Tabata.)

Seiches in Juan de Fuca Strait

In September, high resolution pressure gauges were set in Becher Bay and Port San Juan by the Tides and Currents section to detect intermittent seiche activity believed to originate from edge-wave excitation. These data together with similar data collected in 1978 and 1980 are being analysed to determine phase speeds and structure of the edge-wave motions. Stilling-Well tide gauge records for Victoria and Esquimalt harbours are also being digitized for use in interpreting such motions. (Contact: R.E. Thomson.)

Numerical Modelling

The Numerical Modelling section is involved in development and application of numerical methods in support of a wide variety of observational and theoretical research programs sponsored by the Institute of Ocean Sciences and other agencies. Numerical models are used in the planning and interpretation of field programs, in the design of pollution and inundation countermeasures by the simulation of hypothetical worst-case scenarios, and in the clarification of mathematical theories of wave physics by numerical evaluation of test cases.

Xia Zhong Wan, an exchange scientist from the First Institute of Oceanography, Qingdao, China, spent seven months of his two-year stay at IOS involved in programming and testing a model of the Yellow Sea.

Software for automated set-up of explicit, finite-difference models of tidal, storm surge and tsunami effects in coastal seas was developed and written up during 1981, resulting in very substantial reduction of programming and debugging time for project programmers.
(Contact: R.F. Henry.)

Two projects have defined the requirements for further observational programs. Simulation of internal Kelvin waves in Knight Inlet revealed possible ambiguities in the interpretation of current meter records. Modelling of tides in M'Clure Strait and Viscount Melville Sound, carried out in conjunction with L. Ku (CHS, Ottawa), confirmed that certain suspected anomalies in existing records are serious enough to justify further field studies. (Contact: R.F. Henry.)

Storm surge and tidal modelling studies of the Bay of Bengal, undertaken on behalf of W.M.O., resulted in a proposal for a follow-up international water-level measurement project in this area.
(Contact: R.F. Henry and T.S. Murty.)

Working jointly with Dr. G.A. McBean of the Atmospheric Environment Service, preliminary studies of explosive cyclogenesis over the north-east Pacific Ocean were carried out. Using meteorological data covering a 23-year period, correlations between the rate of deepening of extratropical cyclones and sea surface temperatures and potential layer depths were computed. Also, using concepts of tsunami magnitude developed jointly with Dr. H.G. Loomis (University of Hawaii), an understanding of the energy transfer from earthquakes to tsunamis was advanced. (Contact: T.S. Murty.)

Aspects of the density-driven circulation in the Georgia-Fuca system continued to be studied with the aid of the GF4 and GF5 laterally-

integrated models and three-dimensional models (GF6) of the overall system.

Discharge from the Fraser River, which undergoes strong tidal and seasonal modulation, forms a shallow brackish layer over the deep, denser water in strongly tidal southern Strait of Georgia. A field program has been initiated with Beak Consultants Ltd. to extend and verify earlier collaborative modelling with Dr. J. Stronach on the development of a numerical model (GF4), in which layer thickness and the vertically-averaged layer densities and velocities are computed. Initial results indicate that the basic features of the circulation, in the absence of significant winds, involve a splitting of the emergent stream from the river against the shores of the Gulf Islands opposite. The northerly component contributes to a large clockwise gyre extending over the full width of the Strait while the southerly component moves towards the strong tidal mixing region of the San Juan Islands.

Numerical studies of large-scale, seasonal, density-driven circulation involved sensitivity trials to evaluate the capacity of the models to simulate observed changes in overall scalar distribution. Understanding the relation between the diffusive properties of a scheme and the mesh spacing, in particular with relation to scales encountered on the B.C. coast, is being approached on two major different scales.

On the smaller scale, the laterally-integrated numerical scheme applied in the GF5 format is being used to construct a model of the Burrard Inlet system. This is a collaborative project with Professor R.W. Burling and D. Dunbar of the University of British Columbia.

On the larger scale, extensive analyses have been carried out on results obtained from trials of the three-dimensional, seven-level model GF6 in a collaborative project with Dr. J. Backhaus of the University of Hamburg. A feature of these results concerns potentially important interactions between the overall density-driven circulation and strong local tidal residual circulation. Notable shortcomings of the model in connection with the latter phenomenon have necessitated redesign and calibration to accommodate barotropic mixed tidal simulation.
(Contact: P.B. Crean.)

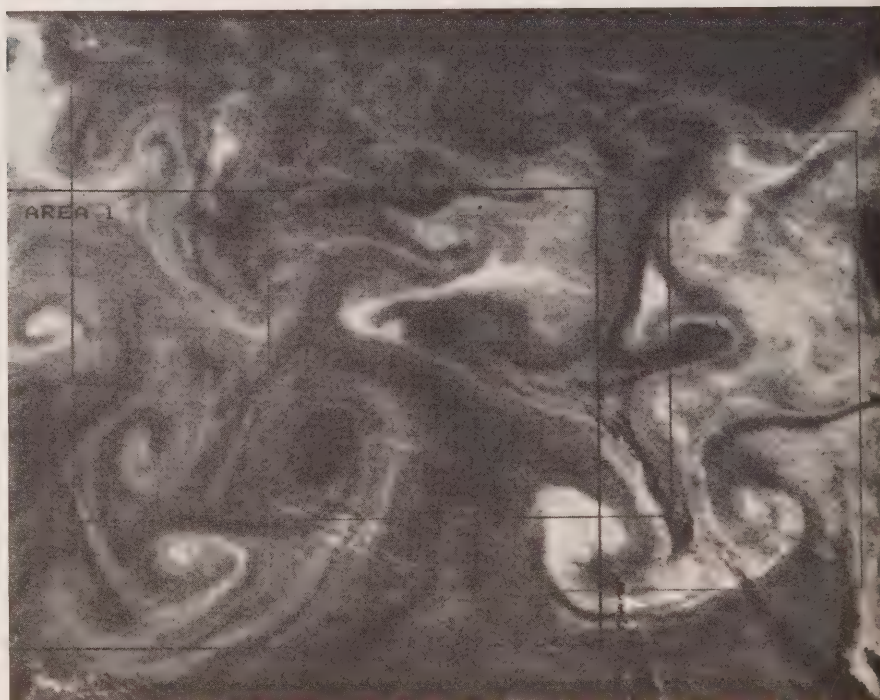
In addition, a method of calculating continental shelf wave profiles and dispersion curves was developed and tested and a study was started on the optimal choice of a finite element method of solving the linearized shallow water equations.

Remote Sensing

The Remote Sensing group at the Institute of Ocean Sciences continued to concentrate its attention on the remote mapping of ocean colour (spectral reflectance) for deducing the surface distribution of chlorophyll-a. This type of work is now being undertaken by numerous groups around the world, but for the most part using only the absorption of blue light by chlorophyll pigments as the means of detection. At IOS, research has led to airborne sensing of natural chlorophyll fluorescence and most recently the investigation of this technique for space application.

An evaluation of this possibility by a consortium of university and industrial groups managed by the Canadian Corporation for University Space Science (CCUSS) has concluded that a suitable sensor could indeed be built and that such work would be a logical and timely extension of developments now being undertaken by Canadian companies. Further studies and construction of a prototype sensor will be undertaken jointly with the Interdepartmental Committee on Space and the Department of Fisheries and Oceans.

Satellite image of an area of the Atlantic Ocean 150 km across showing the surface colouration caused by an extensive plankton bloom south of Iceland on June 19, 1976. The three areas shown have been used to study the spatial properties of two-dimensional turbulence, as described in a recent paper by Gower, Denman and Holyer in the journal "Nature."



Additional studies included analysis of zenith sky spectra demonstrating the complexity of effects that might be encountered through the atmosphere. Data collected at IOS show that atmospheric variation effects should be manageable, but the full range of flexibility and sensitivity of the proposed sensor will certainly be needed. Studies have also been made of chlorophyll fluorescence in B.C. coastal waters. These related especially to the variation of fluorescence efficiency in natural phytoplankton populations.

The international symposium "Oceanography from Space," organized for COSPAR, SCOR, and the IUCRM (Committee on Space Research, Scientific Committee on Oceanic Research and the Inter-Union Commission on Radio Meteorology) in Venice, Italy, attracted about 200 attendees from many countries. The proceedings, Volume 13 of the Plenum Press Marine Science series, contains summaries of the state of the art in different techniques of satellite remote sensing of the oceans.

Other projects during 1981 included: development of an improved multi-channel spectrometer for airborne work, development of software for analysis of satellite imagery, and participation in both NASA's water colour working group and the Canadian Radarsat oceans team.

(Contact: J. Gower.)

Computing Services

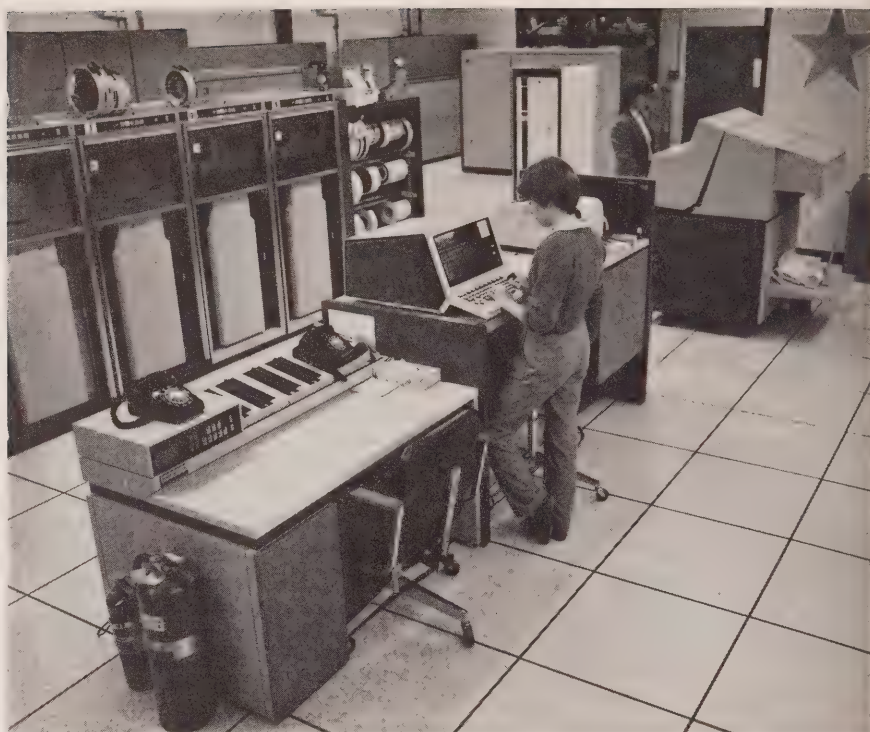
With only a total system down-time of just over two weeks, the old Univac 1106 computer was replaced with a compatible 1100/60 system, with no conversion of user programs or data files being required. The new system includes: 1100/61 Model C1 Central Processing Unit (CPU), 524 K 36-bit words of memory and a Houston DP8S3 incremental plotter.

A floating point systems AP-190L array processor (128 K words) was acquired in March for use primarily in support of numerical modelling studies.

Other improvements included implementation of new plotting hardware (a large on-line Houston plotter) with supporting software. A new level of the Univac operating system (36R2D) and libraries were also installed with the 1100/60. Comparisons indicated that the average cost of runs on the new system was 70% of the cost of those on the previous system while providing nearly 3 times the main memory, 4 times the mass storage, and improved turn-around time.

Development in the area of small computers continued in 1981

*Univac 1100/60 Computer System.
Systems Support Processor and
Operator's Console are in foreground.
The Array Processor is the light-
coloured box in right background.
The 1100/60 CPU and Memory are
immediately behind the Array
Processor.*



through upgrading and acquisitions such as the PDP-11/34 for field hydrography. A year-end survey of small computers used for both oceanographic and hydrographic work, showed 16 mini-computer based systems, 7 large programmable calculator systems, various micro-processor based data acquisition systems, 16 personal computers and over 40 terminals in use with the central computer.

Extensive changes and additions were also made to the automated cartography software. These included: modifications to accommodate the new plotting table, implementation of new versions of GOMADS (Graphic On-line Interactive Editing and Compilation System), and the RSX11M operating system, the addition of a new symbol disc with supporting software for the Kongsberg photoplotter, and implementation of the Digital Data Library (DDL) software on the Univac system.

Ocean Chemistry

The major objective of the Ocean Chemistry Division is to provide expertise, advice and a reasonable scientific perspective on both short- and long-term problems associated with the chemical aspects of the ocean environment.

Five areas are of prime concern: ocean pollution, ocean climate, ocean fluxes, ocean circulation and ocean productivity. A balance must be struck between study of the short-term impacts of societal intrusion and the longer-term consequences to the environment.

The *Hudson 81* circumnavigation cruise provided the opportunity for a month-long study of upwelling areas between Costa Rica and Victoria, B.C. Carbon dioxide (CO_2) and trace metal studies were conducted in the deep-sea trenches off Mexico and central America, over geothermal vents in the East Pacific Rise and in the anoxic basins off southern California.

Enclosed Ocean Experiments

1981 was the second year of the SEAFLUXES (sediment/ecosystem/atmosphere flux enclosure study) program to research pathways, budgets and processes of pollutants and natural compounds in the marine environment. Medium-scale enclosures of sea water and plankton (60,000 - 1,000,000 litres range) in Patricia Bay, B.C. were utilized to sustain a marine ecosystem for experimental studies.

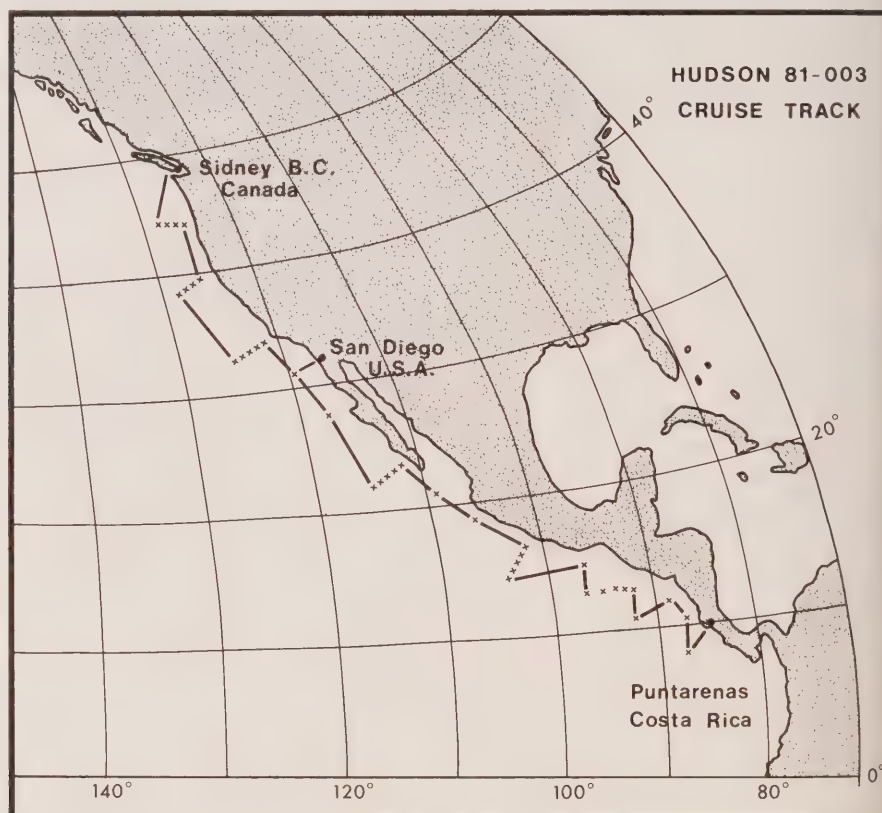
Three experiments were conducted using the controlled-environment, CEPEX-type enclosures. The major one involved a copper-glucose experiment in cooperation with Dr. H. Seki of the University of Tsukuba, Japan. The effect of a simultaneous addition of 4 mg of glucose with 8 μg copper (Cu) per litre of sea water was measured by uptake rates of organic substrates of microorganisms. Drastic reduction of higher trophic levels was observed, in sharp contrast to the effect of just Cu addition without glucose leading to diatom bloom through reduction of grazing pressure. The addition of Cu only was also found to produce increasing sedimentation of organic matter and faster depletion of nitrate in the ecosystem. The second project, undertaken cooperatively with Dr. Handa of Nagoya University and Drs. Takahashi and Ichimura of the University of Tsukuba, studied metabolite production using isotopes of ^{15}N and ^{14}C to trace uptake of ammonia, nitrate and CO_2 by different phytoplankton populations. The third experiment was conducted jointly with Dr. B. Imber of Southampton University and Dr. M. Robinson of Royal Roads Military College to study the metal binding ability of organics associated with heavy growth of single species cultures.

The CHEMCELL sediment/sea water experimental system was attached to the seabottom at Patricia Bay to study its performance characteristics. Dr. F. Pollehne from the Institut für Meereskunde at Kiel, F.R. Germany, contributed to a study of nutrient regeneration using sediments obtained near the site and the rates of fecal pellet and phytoplankton regeneration processes in contact with sediments. (Contact: C.S. Wong.)

Marine Carbon Research Centre

The Ocean Science and Surveys Marine Carbon Research Centre at IOS, now in its third year, is focussing on the marine aspects of the global CO_2 cycle. In recent years the scientific community has expressed increasing concern over global warming, especially as evidenced by a continuing warming trend of Antarctic air temperature. There is a new sense of urgency in understanding the mechanism of the global carbon cycle which determines the time-scale of the "greenhouse effect" of CO_2 . It is particularly important to study the role of the ocean, representing the major sink of atmospheric CO_2 , in the cycle.

Cruise track of the CSS Hudson in the tropical Pacific Ocean; the cruise was used for CO_2 , trace metals and chemical oceanography studies.





This program has two main components: CO₂ monitoring and CO₂ research. CO₂ monitoring is an essential tool in establishing the first signals of oceanic CO₂ increase, the secular increase, and long-term variability. The ocean CO₂ monitoring program is being developed using three types of platforms: ships of opportunity, research ships along Line P, and B.C. lighthouses. Two ships of opportunity are being used: the *Canada Ace* between Nagoya, Japan and Richmond, B.C. with 16 crossings a year in the north Pacific Drift and Subarctic waters, and the *Lillooet*, between Sydney, Australia, and Vancouver, B.C. making 12 crossings a year over the South Pacific Gyre, the Equatorial waters, the North Pacific Central Gyre and the southern edge of Subarctic waters. Such CO₂ time-series will contribute substantially to the data base for CO₂ research and predictive modelling.

CO₂ research in 1981 was highlighted by a study of the marine carbon cycle in the East Boundary waters off the west coast of the North American continent undertaken as part of the *Hudson* expedition. The studies were multi-faceted involving joint participation from IOS, the Bedford Institute of Oceanography, U.B.C.'s Department of

The routes of the Canada Ace and the Lillooet, the ships-of-opportunity engaged in CO₂ monitoring in the Pacific Ocean.

Oceanography, and the Department of Geology at Dalhousie University. Measurements of atmospheric and oceanic CO₂ content, particulate and dissolved organic carbon, alkalinity, nutrients, chlorophyll-a and other supporting oceanographic parameters were made in the coastal waters off Central America, Mexico, California and Oregon. These areas contain upwelling waters which are CO₂ rich.

One of the objectives of the work was to understand the air-CO₂ transfer where deeper waters were brought into contact with the atmosphere. Preliminary data indicate that during the cruise period (April 9 - May 9), the ocean appeared to be absorbing CO₂ from the atmosphere except in the extreme nearshore upwelling areas. In these locations pCO₂ (the partial pressure of CO₂ in sea water) can exceed present atmospheric CO₂ levels of about 345 ppm by as much as 100 ppm (Contact: C.S. Wong.)

Hydrocarbons and Pesticides

The objective of the program is to advance the knowledge of the occurrence, pathways and fate of hydrocarbons (natural, petroleum-based, chlorinated and pesticides) in the marine environment.

PAHs (polycyclic aromatic hydrocarbons) belong to a class of organic compounds that may induce undesirable biological effects. A histological survey of the blue mussel (*Mytilus edulis*) was conducted in Kitimat Harbour and approaches and in Alberni Inlet. In mussel samples collected in 1980 and 1981, abnormal physiological conditions similar to those observed in 1979 samples were absent. A similar histological and chemical survey of the same mussel species was conducted in selected southern Vancouver Island waters. Two types of neoplasms were detected, 12% of which were identified as hemopoietic neoplasm. This prevalence, in agreement with that for mussels in several U.S. bays, is the first reported in Canadian waters. Mussels from Cowichan Bay showed 4% incidence of a gonadal neoplasm, not previously observed in mussels, although documented in soft shell clams from the northeast coast of the United States.

A chemical method has been developed to isolate PAHs and other organics from biological tissues of marine organisms. Constituents can now be isolated in sufficient quantity without loss of chemical integrity for use in short-term bioassays of chemical carcinogens and mutagens. A contaminant-free freeze-dryer was designed to reduce the bulk of biological tissues to a smaller weight by removing 90% of the tissue water.

Participation in the Baffin Island Oil Spill (BIOS) project was mainly advisory: serving as scientific authority and chairman of the Chemical Sub-committee on the chemical fate and effect study. The objective of the project is to compare the impact of undispersed and chemically-

dispersed crude oil in Arctic coastal ecosystems. In the summer, a trial study of the equipment to inject the oil and dispersant, operating procedures and strategy of coordinating personnel and vessels was carried out in Saanichton Bay, B.C. (Contact: W.J. Cretney.)

Trace Metals in Sea Water

The objective of the trace metals program is to assess the distribution and fluxes of natural and man-mobilized metals in the ocean, especially their interactions with suspended matter, the planktonic biota and surface sediments.

A major international symposium on "Trace Metals in Sea Water," funded by both NATO and the U.S. Office of Naval Research, was held in Erice, Italy with seventy invited experts, mostly from NATO countries, to summarize the state of the art of the subject. The main theme centred on determination of accurate levels of trace metals in sea water, especially those established by contaminant-free precautions, and on the implications of such realistic but extremely low levels on biological effect studies and on chemical speciation modelling. (Contact: C.S. Wong.)

The *Hudson* cruise provided an opportunity to study the distribution of metals in open-ocean waters in the tropical Pacific Ocean and in upwelled waters off the North American coast. A profile of contaminant-free samples was collected over the geothermal vent on the East Pacific Rise, using the Patterson-Schaule sampler for lead and mercury. Preliminary data showed that mercury levels were extremely low, averaging 5 ng L^{-1} in the open ocean and being invariant with depth. In the productive upwelled waters, the lowest value was 3 ng L^{-1} . It is possible that organic production removes metals quickly from the surface mixed layer via a detritus flux to the sediment. Similarly, the lowest lead level ever reported, 2 ng L^{-1} , was detected by isotope dilution method in the coastal fjord waters in Alice Arm, B.C. These extremely low concentrations of lead and mercury in sea water illustrate the extraordinary assimilative capacity of the ocean. (Contact: C.S. Wong.)

A NATO-funded program to develop "standard sea water" having trace metals concentrations approximating natural levels is near completion. A long-term storage study on lead, mercury, cadmium, zinc, copper, nickel, cobalt and iron in sea water over a period of almost a year has indicated the feasibility of storing some metals without changes over a long time. Certification of the NATO standard will be a joint effort of Ocean Chemistry Division of IOS and the Jülich Nuclear Research Institute of F.R. Germany under the direction of Professor Nürnberg. (Contact: C.S. Wong.)

A joint Canada/F.R. Germany experiment with Dr. Balzer of Kiel University was carried out in August using the German belljar system over sediment at the Kiel Bight to study the chemical speciation of

chromium. Preliminary results indicated a rapid reduction of Cr(III) to Cr(II) in the sediment but no migration of Cr(III) out of the sediment was detected. (*Contact: R.W. Macdonald.*)

Arctic and Fjord Chemistry

The objective of the program is to gain new knowledge of the environmental factors controlling the circulation and sedimentation in B.C. fjords and in the Arctic. Such new knowledge will contribute to environmental impact statements and assessment of pollutant effects associated with development of the western Arctic for oil and gas, and with industrial activity in coastal inlets of B.C.

The Kitimat fjord system has received attention because of potential oil port development, a proposed methanol factory, and the development of heavy industry in the area. A joint cruise with Ocean Ecology Division and the Pacific Geoscience Centre was conducted to measure the total loading of particulates above the pycocline for the upper reaches of the Kitimat fjord system and to collect sediment cores for lead-210 dating.

Activities concerning the Arctic were mainly limited to summarizing past data jointly with Ocean Information Division. A physical and chemical mass balance study examined metal fluxes and residence times for the southern Beaufort Sea. A study of heavy metals in barites, a material used in drilling fluids, suggested that metal inputs were not significant from drilling operations except possibly in close proximity to well sites. The metals, generally as sulphide inclusions, are not bio-available unless oxidized. (*Contact: R.W. Macdonald.*)

Coastal Pollution

To increase the level of knowledge concerning the effects of mine tailings disposal, IOS embarked on an 18-month research program to study chemical aspects of the mine tailings disposal operation in Alice Arm, B.C.

The chemistry component covers three areas: sediment-pore water interactions; a time-series study of natural river inputs and mine tailings settling; and water column chemistry. Lead isotopes were used to trace the origin and pathways of lead derived from tailings entering the fjord. (*Contact: C.S. Wong, R.W. Macdonald, J.A.J. Thompson.*)

A joint study was conducted with Royal Roads Military College to establish the relative importance of arsenic (As) in mine tailings to overall budget of this metal in Rupert Inlet and adjoining waters. Sea water and sediment samples were collected and analysed for inorganic As(III)/As(V) and organoarsenic species. (*Contact: J.A.J. Thompson.*)

De-toxification mechanisms operating within marine organisms are important in the assessment of pollutant effects. Metallothionein, a metal-

binding protein, has been the subject of cooperative work with Dr. R. Cosson, on a France/Canada Exchange Fellowship. Substantial improvement has been achieved in refining the differential pulse polarography technique to detect metallothionein at a much lower limit of 17 nanomoles, by using a thermostatted cell at 17°C. This procedure was successfully applied to the assay of protein in shellfish.

(Contact: J.A.J. Thompson.)

Ocean Ecology

The ocean ecology program is aimed at increased understanding of the factors responsible for the distribution, production, growth rate and behaviour of marine plankton and the biological and physical factors responsible for the distribution of benthic organisms. These find application in resource extraction and management, and waste disposal into the sea.

Plankton

Two cruises in April and September 1981 concluded a four year study of the planktonic ecosystem off the southwest coast of Vancouver Island. Sampling of the benthos beneath the study area was undertaken by contract to determine if any detectable relationship exists between it and the ambient plankton production. The enhanced primary productivity generated over the southern shelf region that lasts throughout the summer months, appears to result from nutrient-rich waters flowing up the Juan de Fuca submarine canyon in response to pressure gradients caused by a near surface counter-clockwise current eddy.

Statistical analysis methods originally developed in geography/numerical taxonomy have been adapted to allow ecological studies of the coherence scale and geographic pattern of plankton community structure on the continental shelf. Various aspects of the work have been prepared for publication and have been presented at scientific meetings. Discussions with American colleagues from the Pacific Coast states may lead to future cooperative work. Collaboration with NASA is already enabling comparison of satellite imagery with IOS field work. (Contact: K. Denman, D. Mackas.)

Continuous plankton sampling equipment used in these shelf studies and in other situations was improved by adding the capability for counting zooplankton in size classes. This permits a better impression of the make-up of the community. Sampling using ships of opportunity and charters was carried out along a cruise track from Howe Sound to Tahsis

Inlet. This year, for the first time, a rough draft of the data was released within three days of cruise completion, including temperature, conductivity, phytoplankton, chlorophyll, small zooplankton (electronic counter) and solar radiation. The "quick" runs using averaged calibration values suffice for some early warning uses of the data, including, for example, some fisheries management applications. Fully-corrected data were available quite rapidly thereafter.

An attempt to use the same equipment for further work on zooplankton aggregations at salinity fronts was frustrated by dense aggregations of the large planktonic dinoflagellate *Noctiluca*. Experiments with the enclosed ecosystem in cooperation with Ocean Chemistry division involved measuring vertical distribution and timing of grazing. More traditional zooplankton sampling was undertaken in Alice Arm as part of the monitoring study of the Amax mine effluent. (Contact: D. Mackas.)

In the laboratory, continuous cultures of phytoplankton were used to study the effect of varying the frequencies of light fluctuations to simulate the vertical movement of the cells in the water column. Development of a microprocessor-controlled turbidostat and a programmable fluctuating light source was initiated in order to maintain the cultures at a constant population density. Oxygen production, cell size and number, chlorophyll content and nutrient concentration will all be monitored to estimate production under near-normal conditions. Results from these experiments will be coupled with theoretical studies of vertical mixing rates in the ocean to develop models for variations in phytoplankton production as a function of their "recent light history" in the upper ocean. These variations in light level experienced by an organism result from changes in ambient light level itself and from changes in the depth of the organisms within the water column that result from turbulent motions. (Contact: K. Denman.)

The addition of a photosynthetically-active radiation (PAR) sensor improved the vertical sampling array. Another, interfaced to the data acquisition package, provided ambient values at the sea surface. In combination, these allow measurement of the diffuse attenuation coefficient, which is needed for interpretation of satellite measurements of ocean colour. Two sea-going particle counter-multichannel analysis systems to determine the size spectrum of phytoplankton and zooplankton particles were also developed. Some of the developed equipment was also used by the IOS Ocean Chemistry division and the Pacific Geoscience Centre to measure optical and related physical properties of the water column in relation to sediment loading throughout Kitimat Inlet. (Contact: S. Hill.)

Benthos

The IOS benthos program continued to be supported by students and Post Doctoral Fellows. Activities included continuation of studies on reduced oxygen levels in Saanich Inlet and work in Knight Inlet related to high suspended sediment loads. *Pisces IV* performed sixty dives in program support, resulting in 3,000 photographic samples. Professor G. Farrow of the University of Glasgow and Dr. J. Syvitski of the Bedford Institute of Oceanography cooperated in this work. One striking observation involved a forest of gorgonian corals growing on top of the sill at 70 m. Large corals with extended fans that filter particles out of the passing current were seen to act as sails and to effectively pluck meter-sized boulders off the sill during peak tidal flows. Other sills were investigated in Jervis Inlet, Howe Sound and Saanich Inlet, adding to the voluminous data on the relationship between currents and animals, and the identity and distribution of the unique, diverse Pacific fauna. This information is being entered into a UNIVAC retrieval system. This work has generated a considerable degree of excitement in North America and Europe, and has been reported in several seminars and conferences. Monitoring of the effects of hurricane Allan on coral reefs in Jamaica, funded by N.S.F., has continued. (Contact: V. Tunnicliffe.)

The field sampling sector of a program designed to detect the correlation between the productive and unproductive plankton zones on the shelf, the area suffering at times from reduced oxygen levels, and the fauna of the sea bed underlying these has been completed under contract. Sorting and identifying the catch was started, after which the analysis of results will begin. (Contact: R.O. Brinkhurst.)

The oligochaete (sludge worm) toxicity project was successfully completed, linking separate approaches to pollution biology. While some groups of organisms demonstrate different levels of tolerance to specific pollutants in the field, these have not often been used in laboratory tolerance studies. Sludge worms have been used to show how much LC_{50} values of toxicity can be affected by varying simple environmental factors (temperature, pH, salinity), how LC_{50} values relate to survival in nature, and how sublethal responses reveal stresses not seen in normal LC_{50} work. Publications are now in press.

Specimens submitted by pollution biologists, industrial groups and fisheries biologists on a world wide basis have been identified. A theoretical study of evolution in the annelids has been accepted for publication, and several taxonomic reviews have been completed. A guide book to marine oligochaetes is now in press, as is a study of Australian collections. Two students cooperated with these studies, as well as continuing their own work on the *Enchytraeidae* and *Tubificidae*, especially the Pacific coast fauna. Over 7,000 specimens have been examined from British Columbia alone, identifying about 20 new species. Many other

new taxa have been described. A third student is completing a study of the squat lobster (*Munida*) by comparing its respiratory physiology with its resistance to oxygen deficits in the field. (Contact: R.O. Brinkhurst.)

Ocean Information

The Ocean Information Division supports the management, protection and exploitation of marine resources by gathering and disseminating oceanographic information and data, and by providing a marine environmental review service for the Canadian west coast and western Arctic. The division also provides planning, policy and program analysis, and media relations for the Region.

Arctic and west coast marine data compilation and assessment progress in 1981 exceeded expectations. These activities were sponsored jointly by several government departments and industry and were conducted primarily by consultants under contract. Several reports are scheduled for publication in 1982, following final scientific review, as part of the DFO Fisheries and Aquatic Science Report Series. They include: Physical Oceanographic Data for the S.E. Beaufort Sea, Queen Elizabeth Islands, N.W. Passage, Baffin Bay and the Ellesmere Islands, and Southern B.C. Coastal Waters (Georgia and Juan de Fuca Straits); Chemical Oceanographic Data for the S.E. Beaufort Sea and Environs, and the N.W. Passage; and preliminary stages of Marine Biological Data for Benthos, Plankton, Fish and Whales of the Beaufort Sea.

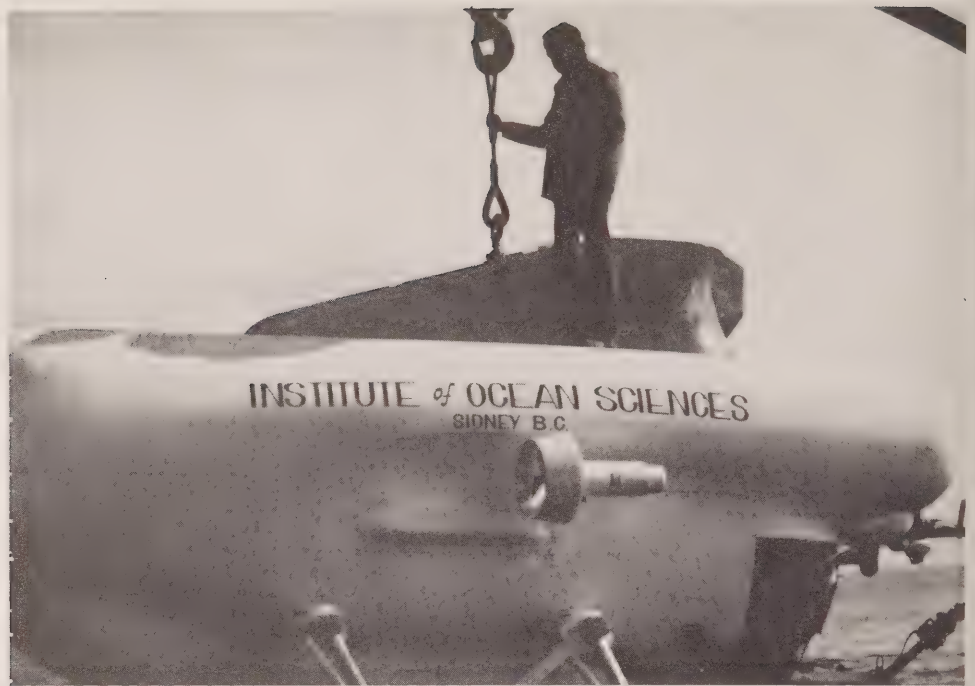
Several reviews of the suitability of the physical, chemical and biological oceanographic data based for environmental impact assessment and climatology studies proceeded under the supervision of regional scientists. In this regard, an overview of Beaufort Sea industrial development projections, a physical/chemical mass balance comparison of some industrial activities vs. natural variability, and an evaluation of the physical oceanographic factors associated with Beaufort Sea oil spill trajectory modelling were all finalized. In addition, a computerized inventory of Arctic marine environmental assessments and data reports was completed.

The appraisal process also involved participation in the Environmental Assessment and Review Process (EARP). Major contributions were made to committees such as the Regional Ocean Dumping Advisory Committee (RODAC), the Arctic Waters Advisory Committee (AWAC), and the Arctic Offshore Development Committee (ARCOD), in light of the accelerating pace of offshore development in the Beaufort Sea. Joint Administration with Environmental Protection Service (EPS) saw the successful completion of several ocean dumping

research projects, a review workshop and a report.

Program analysis and regional planning activities continued to be refined. Considerable effort by IOS senior staff resulted in a well-documented Program Review and Evaluation (PRE) and a five-year Operational Plan for OSS Pacific Region. A considerable number of program analyses and Treasury Board submissions also received regional attention. (*Contact: A.B. Cornford.*)

Ships



Pisces IV being lowered from tender ship.

The IOS Ship Division provided ships, launch, submersible and workshop support during 1981 for Institute, university and other federal agency programs.

CSS *PARIZEAU* (64.3 m overall; 192.9 tonnes)

A/Master: B. Newton *Chief Engineer:* P. Olcen

CSS *Parizeau* was employed for most of the year in support of scientific programs involving the following Institute division: Tides and Currents; Coastal Zone Oceanography; Offshore Oceanography; Ocean Ecology; and Ocean Chemistry. In addition, the *Parizeau* provided support for the geology program of the Department of National Defence. Six weeks of duty as a primary search and rescue (S.A.R.) vessel during the winter herring roe fishery completed the year.

CSS *VECTOR* (39.6 m; 505 tonnes)

Master: K. Sjöholm *A/Chief Engineer:* R. Pearson

CSS *Vector* provided support for the Institute's Coastal Zone Oceanography, Ocean Ecology and Ocean Chemistry divisions. The *Vector* also did sea duty assisting U.B.C.'s Oceanography Department, the Pacific Geoscience Centre and the Environmental Protection Service of the Department of the Environment.

CSS *RICHARDSON* (19.8 m; 78 tonnes)

Master: R. MacKenzie *Chief Engineer:* R. Burrell

CSS *Richardson* spent most of the year in field survey and charting operations for the Hydrographic Division. The Environmental Protection Service was also assisted by the *Richardson* in monitoring studies in Alice Arm. The *Richardson* also spent six weeks as a S.A.R. vessel during the herring roe fishery.

M.V. *PANDORA II*, on charter (58.2 m; 1220 tonnes)

The M.V. *Pandora II* spent most of the year on Canada's east coast, in conjunction with the submersible, *Pisces IV*, assigned to the Bedford Institute of Oceanography.

PISCES IV (6.1 m; 12 tonnes)

Chief Pilot: F. Chambers

The deep-dive submersible *Pisces IV* completed 148 dives in 1981, operating in all three of Canada's oceans. Operations on the east coast, for the Bedford Institute of Oceanography including the Atlantic Geoscience Centre, encompassed work off Sable Island, in the Gulf of St. Lawrence, in the St. Lawrence River, off Newfoundland and Labrador and Baffin Island. Work ranged as far north as Clyde Inlet and as far south as Bermuda as part of a Dalhousie University study.

Barge *PENDER*

The *Pender* acted as mother ship for *Pisces IV* during the first half of the year and later supported the Institute's Hydrographic Division with survey activities in the Okisollo Channel area.

Institute Workshops

The success of the *Hudson 81* Beaufort Sea Survey was in large part due to the work of the depot staff in preparing five Arctic launches. In addition, depot staff completely refitted the launches *Revisor*, *Sprite*, *Sparrow*, *Dove* and *Dellquay* and provided overhaul and maintenance support to *Vector*, *Richardson* and *Parizeau*.

Deck Machinery

Deck Machinery supplied equipment and serviced over 40 major items of support gear for various scientific cruises. Service was also provided during CSS *Hudson's* visit in May and June. Maintenance of support gear to service ships for the Institute, Ministry of Transport, Department of National Defence and various contractors is ongoing.

Management Services

Management Services encompasses the central support services of the Institute — financial and material management, administration, purchasing and library services.

The Marine Technology Centre, built by the British Columbia Development Corporation under federal-provincial auspices, on land adjacent to IOS, was completed and officially opened in June of 1981. Private companies engaged primarily in marine research, development and marketing now fully occupy the centre.

In order to cut energy costs, four solar heating systems were installed for the supply of domestic hot water. This resulted in reduced consumption of oil and electricity. In order to assess the possibility of further energy savings, a contract was let to examine the various mechanical and electrical systems in the Institute.

Twice weekly public tours of the Institute, conducted by the Canadian Corps of Commissionaires, attracted 1,977 visitors during 1981.

The response to the library's new computer-based catalogue has been favourable. A series of refinements were made this year, making the system more adaptable to user requirements. Interest in the system has been expressed by other libraries, including the Maritime Museum of Monaco. The number of library users has increased dramatically as a result of the Marine Technology Centre coming on-line.

DEPARTMENT OF THE ENVIRONMENT

Atmospheric Environment Service

The main scientific activity during 1981 involved continuation of the analysis and interpretation of the Storm Transfer and Response Experiment (STREX) data set. This experiment was a major air-sea interaction study of storms over the northeast Pacific Ocean. A detailed intercomparison of wind tracking capabilities of the ship-borne radar and the NAVAID system has shown that in most cases there was a very good agreement. Most of the bad NAVAID wind values could be removed by simple vertical smoothing. Generally, the average difference between the two systems was less than 8% of the measured wind. A report is almost complete.

An important characteristic of storms is their associated warm and cold fronts. Along these frontal surfaces abrupt changes in meteorological parameters occur, usually accompanied by the most intense weather. The frontal system of November 17, 1980 (briefly described in the 1980 annual report) has been the subject of further study. A comparison of the frontal structure as it passed over CCGS *Vancouver*, and over NOAA's *Oceanographer*, four degrees longitude further east, has shown that the basic structure remained the same but with some important changes in detail. The temperature difference across the cold front became smaller but the moisture content in the warm sector was enhanced. Particularly noticeable was the increasing temperature and decreasing moisture in the region between 500 and 800 mb behind the cold front. This is associated with descending air behind the cold front and low-level divergence.

The second major program entailed collection and chemical study of precipitation in oceanic and coastal regions. Observations at coastal locations in B.C. suggest that the acidity of the rain was slightly more than has been traditionally assumed for unpolluted areas. In order to investigate this more fully an observational program to collect precipitation samples from IOS ships and snow samples at Mount Washington on Vancouver Island was started. The precipitation samples are being analysed for major ion constituents and total acidity at the Inland Waters laboratory in North Vancouver. As yet the results are not numerous enough to draw any conclusions but it is certainly evident that events of high acidity precipitation do occur both along the coast and out over the northeast Pacific Ocean. The origin of the sulphates and nitrates in the samples is not yet clear but is likely a combination of natural marine aerosols and the background air pollution levels that are now worldwide. Over the ocean in particular the measured acidity of open

ocean samples is particularly enhanced by the relatively low occurrence of precipitation.

A third area of activity has been in studies of turbulence and mixing in the earth's boundary layer. Results on the spectral shape and empirical constants for the spectrum of microscale temperature fluctuations were found to be in general agreement with previous findings. However, the enhancement of the spectrum at scales where the molecular effects dominate were not observed. It is not yet clear why this is observed in some results and not in others.

The effects of larger-scale atmospheric turbulence were studied in cooperation with a summer student. A model for the development of the mixed layer and its effect on pollution diffusion was applied to a single tall-stack source of pollution. Significant changes in the ratio of dry deposition of pollutant to what is retained for later precipitating out, were caused by varying the mixed layer depth throughout the course of a day. (*Contact: G.A. McBean.*)

Canadian Wildlife Service

The Canadian Wildlife Service (CWS) is responsible under the Migratory Birds Convention Act for the preservation of migratory birds. Migratory birds among others include birds at sea, birds along marine shores and those in marine breeding colonies. In order to assist preservation of marine birds, CWS studies their numbers and seasonal distribution at sea, their food habits and their feeding, and their staging and nesting habitats. Seasonal observations on the birds' food habits and feeding, staging and nesting habitat may show "why" the birds are there. Data on the "where, when and why" of marine bird populations aid in delineating marine bird concentrations and vulnerable marine bird habitat.

In conjunction with other colleagues, work has continued on the assembly of an atlas detailing the distribution and density of marine birds along Canada's west coast. Chevron Canada Ltd. has been assisting with the preparation of the atlas to make it available for the environmental hearings relating to B.C. offshore development activity.

Cooperative cruises for next summer are planned by CWS, the Pacific Biological Station (DFO) and IOS to study the distribution and density of marine birds in relation to their foods and physical oceanographic parameters in the Queen Charlotte Sound and Hecate Strait. Possible future offshore drilling may affect both the birds and their prey.

Studies on the feeding ecology of marine birds and the effects of mine tailings on coastal marine life were undertaken and will also be continued on Canada's west coast in 1982.

One investigation of the effects of the El Salvador copper mine in Chile on marine intertidal life and marine birds initiated in the autumn of 1981 as part of CWS/Latin American program will be continued in the spring of 1982. (*Contact: K. Vermeer.*)

**DEPARTMENT OF
ENERGY, MINES AND RESOURCES**

PACIFIC GEOSCIENCE CENTRE



Pacific Geoscience Centre at IOS.

Earth Physics Branch and Geological Survey of Canada

Chief Scientist's Foreword

The purpose of the earth science program is to provide geological and geophysical information on the evolution, structure and dynamic processes of the solid earth and the hazards associated with natural and induced geological processes, with special reference to the western Canada land mass and offshore regions.

The projects described on the following pages have provided data for a number of aspects of these broad objectives. In particular, marine programs have provided data for the development and extension of ideas about contemporary and past plate motions along the western continental margin. These studies, coupled with expansions of the seismological network, levelling, and geodynamic surveys, are continually improving understanding of earthquake mechanisms, frequency and risk. Systematic marine surveys in cooperation with the Hydrographic Service are also playing a vital part in providing a data base for the evolution and understanding of the mineral resources that may occur in Canada's western offshore areas.

Geological studies have been directed towards an understanding of the history of the rock formations along the margin and of the deposition, composition and stability of sediments on the continental shelf and in coastal inlets. These studies provide input both into resource evaluation and into assessments of the environmental impact of the wide range of construction and development projects occurring along the coast and of offshore petroleum exploration.

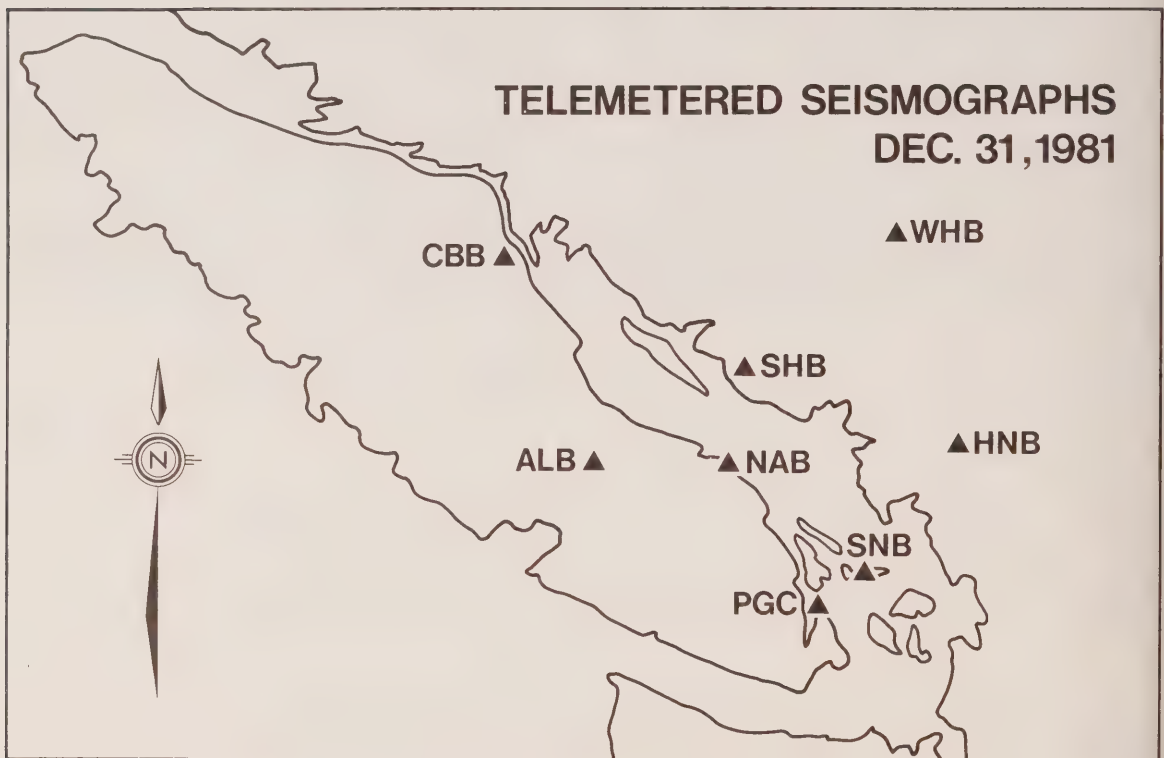
Inland, geothermal studies continued to explore and delineate alternative energy sources and to provide important scientific information about deep crustal structure. Gravity surveys in the Rocky Mountains continued as part of the long-term regional coverage of the northern Cordillera, now the principal remaining gap in the National Gravity Data set.

During the year, a number of new staff joined the Pacific Geoscience Centre (PGC) and there was one important retirement. The Chief Scientist, Dr. W.G. Milne retired after 35 years of government service and 30 years on the west coast. Dr. Milne was transferred to Victoria to operate the seismological observatory soon after the 1946 Vancouver Island earthquake. He presided over a number of organisational changes and expansions culminating with the Victoria Geophysical Observatory

and the Marine Geology Section of the Geological Survey being combined into the Pacific Geoscience Centre in 1978. The scientific success of PGC owed much to his quiet but strong supportive style of management and he will not be easily replaced.

Seismological Service

The Seismological Service provides earth scientists, civil engineers, resource development industries and the public with basic earthquake data, and with research information concerning natural and induced earthquakes, ground motion, seismic risk, earth structure, and nuclear explosions. This is accomplished through a network of seismological stations, including standard and regional stations, two telemetered arrays, strong motion accelerographs, and special installations.



The West Coast Telemetered Network (WCTN) for earthquake monitoring currently comprises 8 seismic stations whose signals are transmitted to a central computer at PGC. Automatic monitoring of these signals permits virtually on-line location of seismic events in southwest British Columbia.

Seismic Networks

The Western Canada Telemetered Network (WCTN), established in order to provide centralized, on-line monitoring of seismicity in southwestern B.C., was expanded in 1981 through the installation of a radio link at Saturna Island which permitted the addition of stations at Sechelt and Campbell River. A telephone-linked station was also added at Whistler, B.C. which will permit seismic monitoring of any future volcanic activity in British Columbia's Garibaldi volcanic belt. Six stations were being recorded at PGC at the end of the year. Preparatory site work was also completed for an additional six stations. The network located almost 200 small earthquakes in the Vancouver Island - Strait of Georgia region in 1981. (*Contact: D.H. Weichert, M. Bone, A. Whitford.*)

The strong motion seismograph network in western Canada, which consists of instruments designed to operate and record ground acceleration only when very strong ($\frac{1}{2}\%$ of normal gravity or larger) earth motion occurs, remained at 36 accelerographs, although some site changes were made. During 1981, 61 auxiliary strong motion instruments called seismoscopes were decommissioned. (*Contact: D.H. Weichert, H. Bennetts.*)

In 1981, the responsibility for locating and cataloguing earthquakes in western Canada was transferred from the Earth Physics Branch in Ottawa to the Pacific Geoscience Centre. Over 700 earthquakes were located in western Canada in 1981. (*Contact: R. Horner.*)

Special Earthquake Studies

In separate cooperative projects with Dome Petroleum Ltd. and B.C. Hydro and Power Authority, seismograph stations were set up to monitor earthquake activity for local seismic risk estimates in the Beaufort Sea region and in northern British Columbia. The seismograph records are sent to PGC for analysis. Beaufort Sea seismicity was also studied by deploying ocean bottom seismographs in a cooperative project with the Atlantic Geoscience Centre and Dome Petroleum Ltd. (*Contact: D.H. Weichert, G.C. Rogers.*)

A two-month field project was carried out in the Frank Slide area in southwestern Alberta where residents had felt minor tremors. Some microearthquakes were observed in the region but none that could be associated with the slide itself. (*Contact: D.H. Weichert.*)

The earthquakes occurring within the subducted oceanic Juan de Fuca plate beneath southwestern British Columbia have been studied and a source-mechanism hypothesis based on volume and density changes resulting from phase changes has been developed. (*Contact: G.C. Rogers.*)

A study was completed relating the earthquake occurrence rate to relative plate motion rates along Canada's western margin. In most

regions there is good agreement between the two, but the convergent margin of southwestern B.C. and Washington appears to require considerable aseismic motion. (*Contact: R.D. Hyndman, D.H. Weichert.*)

A study of the earthquake rate in British Columbia's recent volcanic zones showed a slightly higher rate of small earthquakes there than in the surrounding regions. However, no earthquakes could be associated with any particular volcano. (*Contact: G.C. Rogers.*)

Seismic Risk Estimation

PGC continued to produce site specific risk estimates for many engineering projects in western Canada. New techniques for risk calculation were investigated and considerable progress was made towards the generation of the base maps that will form the basis of a new national seismic zoning map for Canada. (*Contact: D.H. Weichert.*)

Earth Structure by Seismic Methods

One of the most important techniques for determining the deep structures and properties of the earth is the study of waves propagated by explosions or earthquakes. The principles and many of the techniques are similar to those applied by the petroleum industry to the study of sedimentary basins and their structure. The work includes a wide range of theoretical and field investigations including deep crustal and shallow sedimentary programs. The deep crustal programs are directed mainly toward defining the structure in the principal earthquake generating zones along the continental margin.

Theoretical Studies

The theory of resonant scattering for fluid-filled inclusions has been applied to seismological configurations. It has also been extended and applied to wavefield inversions for refraction and reflection interpretation of crustal structure. Previously developed techniques for the inversion and modelling of seismic refraction data have been applied to the data from a major seismic experiment, VISP-80, across the margin of southwest British Columbia. Analyses have also been carried out on data from California and from Antarctica.

Further studies have been conducted on the techniques of wavefield transformation and wavefield continuation. (*Contact: G.A. McMechan.*)

Field Studies

The structure and subsidence history of the Queen Charlotte Basin has been studied using data from seismic profiles, Shell Canada Resources Ltd. well data, and data obtained in cooperation with the University of B.C. in recent seismic refraction studies using a large airgun (32 litres) and sonobuoys. The basin has been modelled in terms of flexure of the continental lithosphere generated by underthrusting along the margin and the formation of a rift in Queen Charlotte Sound. (*Contact: C.J. Yorath, R.D. Hyndman.*)

The analysis of the structure of the Winona Basin off northern Vancouver Island has been continued by applying the theory for sedimentary anisotropy to seismic refraction and reflection data. (*Contact: E.E. Davis.*)

Deep Sea Drilling Project

A leg (78B) of the Deep Sea Drilling Project (DSDP) re-occupied a deep crustal hole on the mid-Atlantic ridge for a wide range of downhole geophysical measurements. They included: a complete suite of commercial well logs, downhole temperature, downhole magnetometer, televiwer, water chemistry, and a packer permeability experiment. There was also the emplacement of a downhole seismometer for use in an oblique seismic experiment in conjunction with ocean bottom seismographs. The results have provided considerable new information on the deep structure, physical properties and state of the oceanic crust. (*Contact: R.D. Hyndman.*)

Geothermal Studies

The earth's temperature influences both rock properties and geological processes. Thermal data, particularly surface heat flux, are among the most important indicators of deep tectonic processes and the structure of the earth's crust. Most active tectonic processes that result in mountain building, earthquakes and volcanism originate from thermal energy. In addition, the earth has considerable economic potential as a heat source for geothermal energy.

Measured thermal parameters include surface heat flux (the result of vertical temperature gradient multiplied by the thermal conductivity of the rocks), and heat production from natural radioactive decay in crustal rocks (for example, thorium and potassium). Studies cover a wide range of geological and geophysical interests — from heat flow, heat production and thermal processes in the deep sea floor, to the discovery and development of geothermal energy resources in western Canada.

Land Studies

There is a continuing program to determine the regional geothermal heat flow pattern from borehole measurements in the Canadian Cordillera. These data can be used in the interpretation of regional tectonics and structure, and in the delineation of hot areas with potential for geothermal energy development. In south central British Columbia, several deep boreholes have been drilled in and near Tertiary sedimentary basins that may be hot water sources for economical space heating. A profile of shallow (100 m) geothermal heat flow boreholes have also been drilled across south central B.C. as part of a general regional evaluation. Studies are continuing in the Garibaldi Volcanic Belt where at Meager Mt., B.C. Hydro and Power Authority has recently drilled potential steam production wells. (*Contact: T. Lewis.*)

Marine Studies

A series of repeat marine-probe heat-flow measurements has been carried out up the length of Jervis Inlet to investigate further the previously observed increase of heat flow as the Garibaldi Volcanic Belt is approached. The large increase in heat flux by a factor of two is observed to take place near the head of the inlet over a distance of 20 km. (*Contact: T. Lewis.*)

Marine heat flow data from the deep water Winona sedimentary basin off northern Vancouver Island have been analyzed, and, along with other geophysical data, indicate the youth of the sediments and underlying oceanic crust. The estimated high temperatures in the sediments also help explain the unusual seismic velocities observed. (*Contact: E.E. Davis.*)

A suite of new heat flow measurements across the Queen Charlotte fault zone substantiates a model of ocean floor underthrusting beneath the Queen Charlotte Islands. Additional measurements were also made in Queen Charlotte Sound to evaluate a proposed rift or extension origin for this area. (*Contact: R.D. Hyndman.*)

The heat flow in Hecate Strait and Queen Charlotte Sound has been estimated using older data from wells of Shell Canada Resources Ltd. These results and paleoheat flow from vitranite reflectance data have been employed to constrain thermal models for the area and estimate probable petroleum maturation. (*Contact: R.D. Hyndman, C.J. Yorath.*)

Deep (10 m) piston corer-outrigger sensor heat flow measurements over Mesozoic sea floor in the northwestern Atlantic were carried out to confirm the results of the previous year's multiple penetration instrument (3 m) survey. The heat flow is found to be constant from 110 to 150 Ma and higher than that predicted by lithospheric plate or boundary layer cooling. (*Contact: E.E. Davis.*)

Repeat temperature measurements in Deep Sea Drilling Project Leg 78B have resulted in an interpretation in terms of downward seawater flow into permeable crustal horizons. Downhole temperatures into old Atlantic sea floor (DSDP site 534) have shown agreement with nearby marine probe measurements. A review of all recent DSDP heat flow measurements has also been undertaken. (*Contact: R.D. Hyndman, E.E. Davis.*)

Gravity

The principal task of the Gravity and Geodynamics Division is to establish the shape of the geoid in Canada to the highest standards and to determine the value of gravity on a regional basis over the Canadian landmass and offshore areas. The geoid is the reference surface for all surveying and mapping. The regional gravity data provide information for both the determination of crustal structure and the evaluation of resources and are critical to the operation of inertial navigation systems used by defence agencies for submarines and missiles.

Seaborne operations in 1981 aboard CSS *Parizeau* covered an area of 87,000 km² on a systematic 10 km line spacing out to the 200 mile limit west of the Queen Charlotte Islands. Two La Coste and Romberg dynamic gravimeters were operated simultaneously: SL1, the "linear" prototype meter tested in 1980 and a three-axis "beam" meter, S41. Comparison of the two systems again showed that the linear meter performed with greater accuracy. In particular, because of the reduction of cross-coupling due to ship movement, it was much more tolerant of rough water.

The 1981 survey will be integrated with the continuing series of regional offshore surveys for publication in 1982. A suite of extended single tracks cutting across the offshore region was successfully used to provide the basis for a mutual adjustment and calibration of these surveys into one coherent data set comprising all west coast marine gravity data.

Land regional gravity surveys by helicopter were continued under contract in the Jasper-Edson area of Alberta and British Columbia by Terra Surveys Ltd. As in previous years, a combination of existing monumentation and inertial navigation was used to provide the required ± 50 m horizontal and ± 3 m vertical control. Three hundred new stations were observed including one on the summit of Mt. Robson at 3950 m. (*Contact: R.P. Riddihough, D. Seemann.*)

Geodynamics

In the active tectonic region of Canada's west coast, the major subject of study for geodynamics is the effects of contemporary crustal deformation. A principal objective of such studies is to establish realistic dynamic models of crustal plate interactions and their accompanying earthquakes in this region. Efforts to measure crustal strain using precise gravimetry continue on central Vancouver Island in the region of the 1946 earthquake. Semi-annual gravity surveys since 1977 continue to show regional gravity field changes of the order of 3 to 5 $\mu\text{Gal/a}$ ($1 \mu\text{Gal} = 10 \text{ nm/s}^2$). Although a tectonic origin cannot be ruled out, it is thought that secular variations in local hydrology may be the principal cause of these gravity variations.



The measurement of small changes in elevation over periods of a few years is extremely difficult especially in regions with limited road access. Using very sensitive gravimeters transported by helicopters or float-aircraft, vertical strain measurements can be carried out over long distances in the rugged terrain of Canada's west coast.

In an attempt to measure differential vertical strain over longer (~ 100 km) baselines, a precise gravity profile was established between the Tofino and Pt. Atkinson tide gauges using float-aircraft for instrument transport. This innovative survey method proved extremely successful. Relative gravity values were established to a precision of $2 \mu\text{Gal}$ which should allow resolution of future elevation changes of the order of 1 or 2 cm.

Work preliminary to the measurement of horizontal crustal strain was also initiated. For the eventual precise measurement of baselines of up to thousands of kilometres using VLBI (very long baseline interferometry), the site of the Dominion Radio Astrophysical Observatory at Penticton was investigated for possible use in conjunction with NASA's ARIES program. On a more local scale, the sites of a 1947 horizontal triangulation network in the Gold River area were recovered for future trilateration measurements. It is hoped that the precise measurement of baselines up to 40 km in length with laser-ranging instrumentation will allow future strain estimates of the order of 1 part in 10^7 . (*Contact: H. Dragert.*)

Geomagnetism

The Geomagnetic Field

The earth's geomagnetic field varies both spatially and temporally. This inherent variability of the geomagnetic field is well known and is exploited in a variety of ways. To be utilized for navigation, the magnetic field and its gradual change with time must be determined as a function of latitude and longitude. Changes in the magnetic properties of rocks also lead to spatial variations in the magnetic field which become characteristic signatures of structure, composition, and the thermal history of crustal rocks. Short-period temporal changes in the magnetic field must be monitored in order to resolve subtle spatial field variations as encountered in exploration geophysics.

In Canada, the geomagnetic field is monitored continuously at 13 primary observatory sites and discontinuously at about 140 secondary sites. As part of this Canadian Geomagnetic Network, the Pacific Geoscience Centre operates the Victoria Geomagnetic Observatory (VGO) on property near the Dominion Astrophysical Observatory. In the fall of 1981, a third generation Automatic Magnetic Observatory System (AMOS) was installed here. This system, which uses both fluxgate and proton precession magnetometers, now features self-diagnostic testing, variable sampling rates, and remote data retrieval via a telephone modem to a central repository in Ottawa.

The Pacific Geoscience Centre also collects magnetic field observations at the 15 repeat stations in British Columbia. These measurements, repeated 2 - 3 times every 5 years, provide the secular variation data that supplement the primary network. These data are used in updating maps of the geomagnetic field components for the Canadian land mass every 5 years. During the summer of 1981, measurements were obtained at 3 of these sites.

Geomagnetic Variations

Temporal variations in the earth's magnetic field provide a source of electromagnetic energy with which to probe the earth's electrical conductivity structure. Zones of high conductivity, if related to high temperatures and partial melting, can be used to define areas of geothermal interest. Geomagnetic depth-sounding can also determine the thickness of the cold lithospheric plate riding over the asthenosphere, an important parameter in understanding the active tectonic regions dominant on the west coast.

Confirmation that the cold Juan de Fuca lithospheric plate does indeed dip beneath the continental mass under Vancouver Island has been derived from an analysis of the geomagnetic data obtained in a 1980 experiment. Experimental results also imply that the thickness of the Juan de Fuca plate increases with its age, substantiating previous studies.

Ocean bottom magnetometers (OBM) have proved to be excellent sensors for measuring the magnetic signatures of mass water transport, such as those attributed to the lunar semi-diurnal tides. Good recordings of deep water tides have been obtained at the two sea floor sites: the base of the continental slope (2200 m water depth) and 80 km further west on the abyssal plain (2700 m water depth). Shorter period fluctuations (less than 1 hour) associated with oscillatory current flows have also been measured for the first time in deep waters. Preliminary research suggests that an oceanographic edge wave along the continental slope may be responsible for these shorter period magnetic signals.

The Pacific Geoscience Centre is also developing a unique geophysical instrument to determine the distribution of electric conductivity in the first few tens of kilometers beneath the seafloor. Usually OBMs measure the earth's natural magnetic field variations; alternatively, an artificial source of electromagnetic energy can be generated by placing a vertical wire from the sea surface into the sea bottom and pumping electric current through the cable. The resulting magnetic field is measured by OBM sensors on the seafloor. From these observations a knowledge of the conductivity of the sediments and the crust beneath the ocean can be deduced. The theory has been worked out and a test of the procedure was done in November 1981, in the Strait of Georgia. The precise positioning required to maintain an exact, known

geometry between the source cable and the OBM's was successfully achieved.

In order to determine the conductivity structure beneath Vancouver Island more precisely, many samples of variations in the electromagnetic field components are required over a number of sites. Consequently, in 1981, two sites were selected in central Vancouver Island and measurements of the electromagnetic field were obtained. Repeated observations at these sites will be done in the future in order to monitor possible temporal changes in crustal conductivity structure.

(Contact: L. Law, J. DeLaurier, D. Auld.)

Paleomagnetism

The paleomagnetism of rocks records the variations in directions of the geomagnetic field in the geological past. The intensity of the ancient field is also recorded but is much more obscure and difficult to observe and can only be obtained in very favourable circumstances. The principal application of paleomagnetism is in tectonics — the study of the motion of continents, the opening and closing of oceans and the origin of mountain belts — but it is also used widely in many problems of stratigraphic correlation, the origins and thermal history of rocks, and in the source and origin of magnetic anomalies.



The paleomagnetic laboratory currently being installed at PGC includes two microprocessor controlled spinner magnetometers used to measure the remanent magnetic fields in rock samples. The raw data are communicated directly to the mainframe computer for analysis.

A new paleomagnetic laboratory is currently being installed at PGC. Work will be related mainly to studies of the tectonics of the Cordillera and the western Arctic and to magnetostratigraphic studies. During the last decade, geological and geophysical studies have shown that the Cordillera comprises a number of distinct crustal blocks. Vancouver Island is one such block. Paleomagnetic work has shown that these blocks have been transported from the south by distances over 1000 km, much of central British Columbia once being in the latitude of California. Vancouver Island could have moved northward by over 5000 km relative to North America and may even have originated on the other side of the Pacific Ocean. The western Cordillera, therefore, appears to be a collage of small crustal fragments that originated elsewhere, were carried over large distances, and finally glued to North America. This discovery has led to a profound revision of our ideas about the origin of this and other mountain belts. (*Contact: E. Irving.*)

Geological - Geophysical Studies

Systematic magnetic, gravity and bathymetric surveys are being conducted over the Canadian Economic Zone to help assess the economic potential of the region and its tectonic framework. The 1981 Resource Mapping Program survey was conducted between 180 and 360 km west of the Queen Charlotte Islands (approx. 50°N to 54°N). Continuous magnetic, gravity and bathymetric data were collected in 7700 km of survey and tie lines in this previously unsurveyed area of the northeast Pacific. The new magnetic data exhibit an extremely regular sequence of north-northwest trending oceanic anomalies with little evidence of offsets or transformations and a half-spreading rate of approximately 3.0 cm/year. The most striking bathymetric features were two submarine channels striking subparallel to the magnetic anomalies. (*Contact: R. Currie.*)

Geological studies on the Queen Charlotte Islands and concurrent geophysical programs in Hecate Strait and Queen Charlotte Sound have led to new interpretations of the tectonic history and petroleum potential of Queen Charlotte Basin. The recognition of the origin and timing of collision of exotic crustal fragments and the rift origin of Queen Charlotte Sound has permitted new geophysical modelling of the dynamics and thermal history of the basin. Two possible sources of hydrocarbons are indicated. The first is related to the possible occurrence of petroliferous Upper Triassic and Jurassic rocks beneath southern Hecate Strait similar to those observed on the Queen Charlotte Islands. Rifting in Queen Charlotte Sound possibly has allowed these older

hydrocarbons to migrate upward along faults to become trapped within the Tertiary sediments. The second source for hydrocarbons lies within the Tertiary sediments themselves. The subsidence and thermal history of the basin suggest that sufficient metamorphism of organic matter would have occurred. If petroleum source rocks are eventually found, favourable reservoir rocks within the basin may contain liquid hydrocarbons of Tertiary age. (*Contact: C.J. Yorath.*)

Paleontology

Activities in Paleontology at the Pacific Geoscience Centre are focused on micropaleontological biostratigraphy of Mesozoic and Cenozoic rocks of the complex Pacific margin of Canada. Work is continuing in studies of Tertiary biostratigraphy both on land and offshore with emphasis on depositional environments and planktonic foraminifers. Ultimately, this study should assist in understanding the tectonic evolution of the west coast and its potential for oil and gas exploration. In connection with the latter, a very successful two-day symposium was held at PGC in February. This meeting was designed to familiarize the oil industry with the tectonics, sedimentary history and possible hydrocarbon occurrences in the offshore areas of British Columbia.

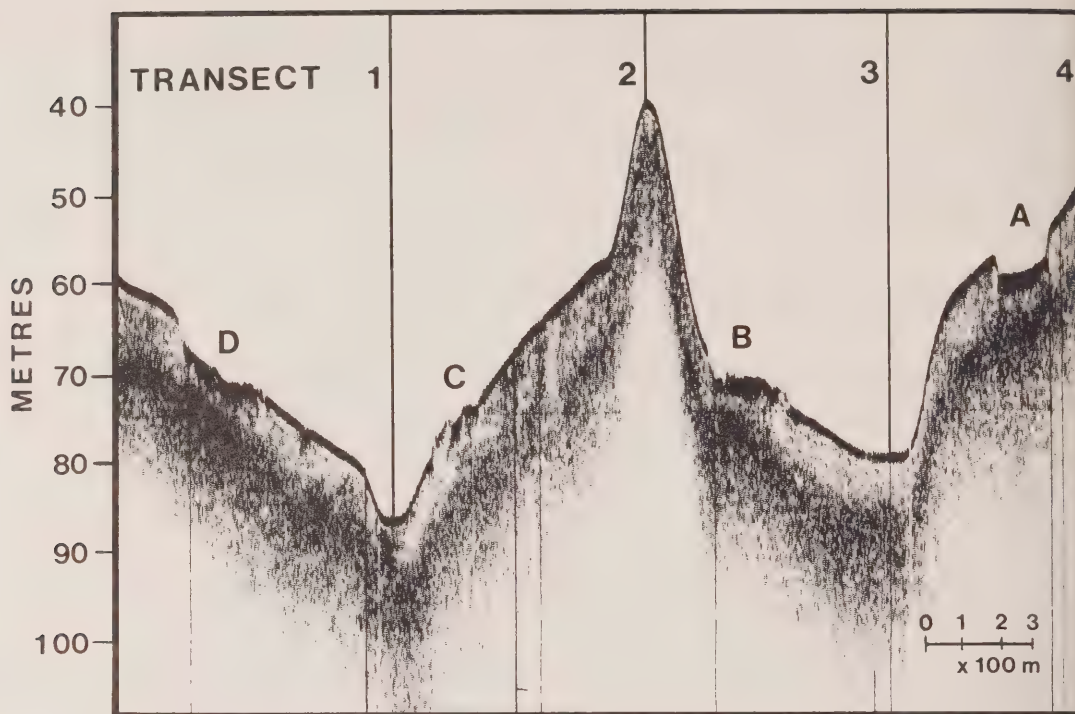
The geology and biostratigraphy of the Jurassic rocks of the Queen Charlotte Islands are currently under intensive study. This work includes microfaunas (Cameron, PGC) and ammonoid faunas (H.W. Tipper, GSC, Vancouver and H. Frebold, GSC, Ottawa).

A Master's thesis supervised by B. Cameron was completed by M.L. Malott in 1981 at U.B.C. It dealt with the distribution of Holocene foraminifers from deep sea cores off the Pacific margin. Malott and Cameron are continuing studies on foraminiferal and ostracod distributions in Quaternary sediments of the west coast. (*Contact: B. Cameron.*)

Sedimentology

Estuarine and Marine Delta Sedimentation

Demand has continued for geological data from the Fraser Delta which can contribute to the formulation of environmental/engineering guidelines. This past year, attention has been focused on assessments of



Bathymetric profiles of the head of the Fraser River Delta Slope off the Iona Island Sewage Treatment Plant outfall channel. The record depicts successive transects across the same corridor and suggests the presence of a slump generated trench and associated downslope deposits: A. trench, B. slump deposit, C. slump deposit, D. intermediate trench/slump deposit morphology.

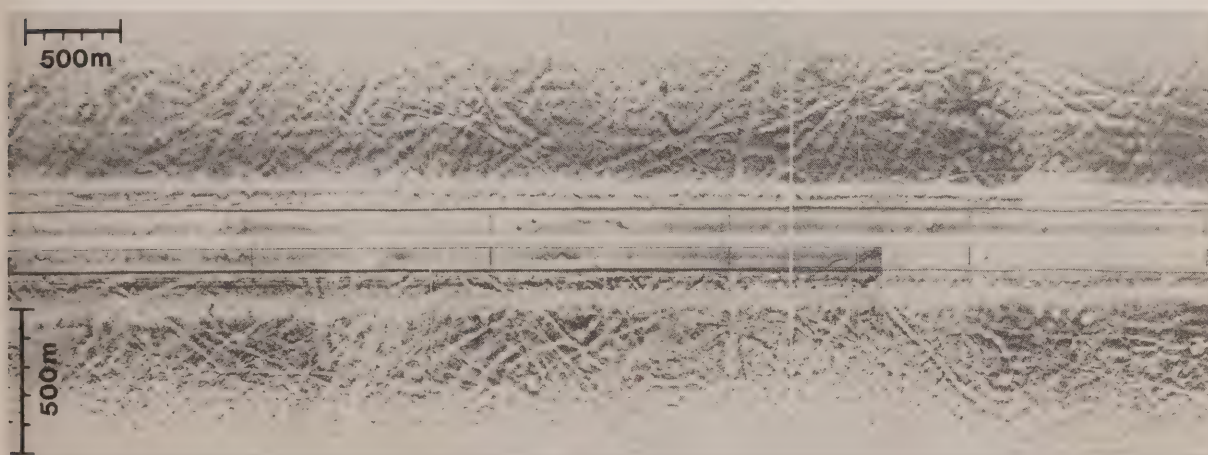
the stability of the Fraser Delta slope. The research has included analyses of sedimentologic, geotechnical, morphologic and bathymetric data and has been performed in conjunction with the Soil Dynamics Group in the Department of Civil Engineering at the University of British Columbia. (Contact: J.L. Luternauer.)

Continental Shelf Sedimentation

A study of the late Quaternary morphology/sedimentation in Queen Charlotte Sound, completed in 1981, established that much of the shelf reflects the widespread effects of Pleistocene glaciation; both broad glacier scoured troughs containing ice-contact deposits and well-defined iceberg furrows are still apparent. The oceanographic climate which prevailed when sea level was lower probably determined the depth of the present shelf break and contributed to the concentration of heavy minerals on banks and to the formation of canyons which crease bank margins. The little terrigenous material that has been supplied to the shelf during the Holocene is accumulating near the mainland coast. Elsewhere on the shelf

the principal post-glacial deposits are foraminiferal and molluscan skeletal detritus which can be dominant components of bank sediments. (*Contact: J.L. Luternauer.*)

A joint cruise with scientists from Western Washington University was undertaken to southern Hecate Strait to study the morphology and sediments on a broad bank approximately 2500 km² in area. Traditional geological opinion has held that shallow marine carbonate sedimentation is essentially confined to tropical and subtropical latitudes. There is growing evidence that under appropriate conditions, carbonate-rich sediments can develop on continental shelves at any latitude. This investigation was carried out to learn more about such high-latitude biogenic and mixed biogenic-terrigenous sediments. Much of the bank is covered by a veneer of coarse sands and gravels, in places composed entirely of shells and shell fragments. Across this gravel and shell pavement in the interior of the bank are frequent narrow, long "ribbons" of sand formed into oscillation ripples and mega-ripples up to 2 m high. The edges of the bank, where fine sands dominate, are characterized by asymmetrical current ripples up to 4 m high with wavelengths of 10 m or more. (*Contact: B. Bornhold.*)

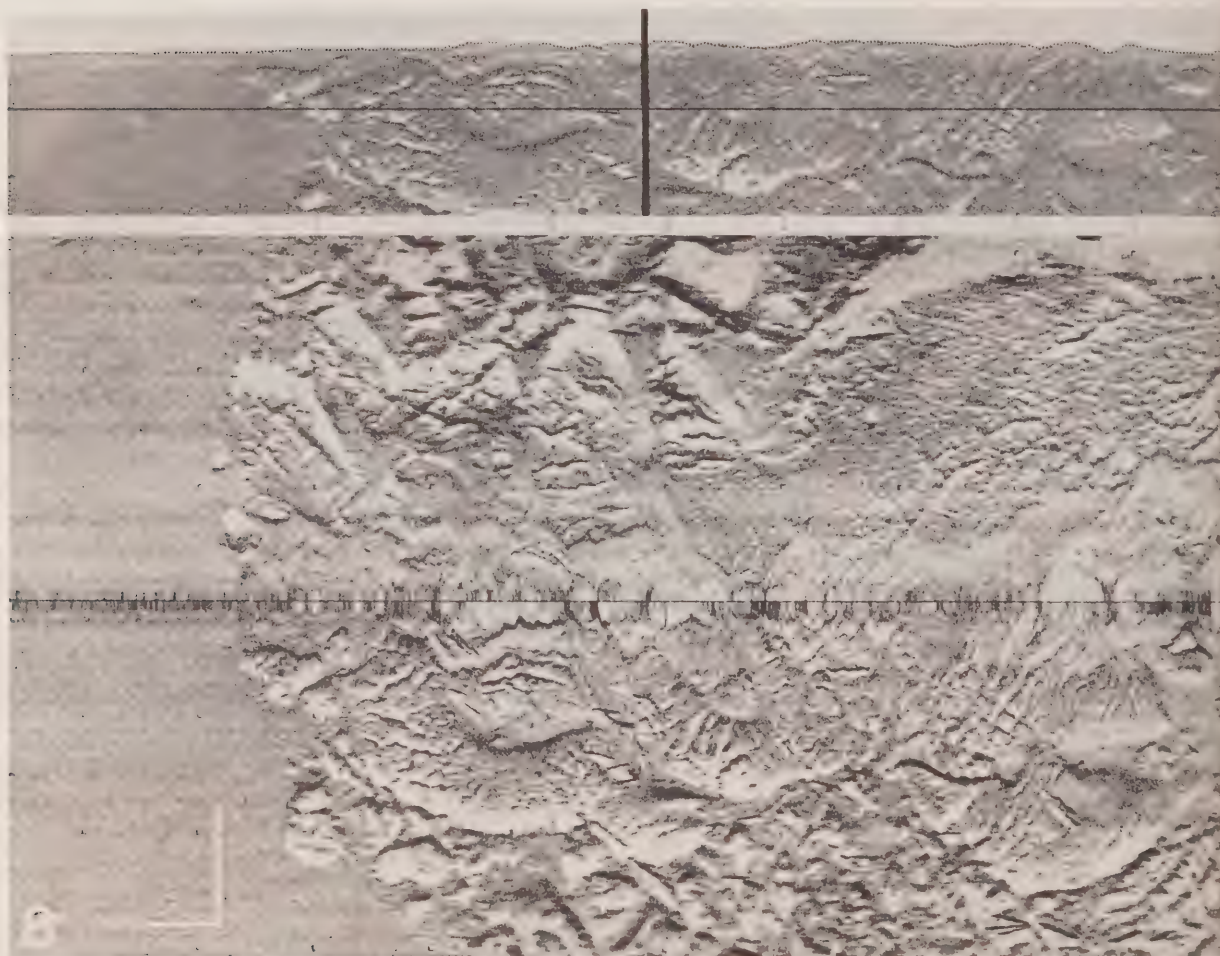


Side-scan sonogram of criss-crossing iceberg furrows at a depth of about 170 m on the inner shelf of northern Queen Charlotte Sound.

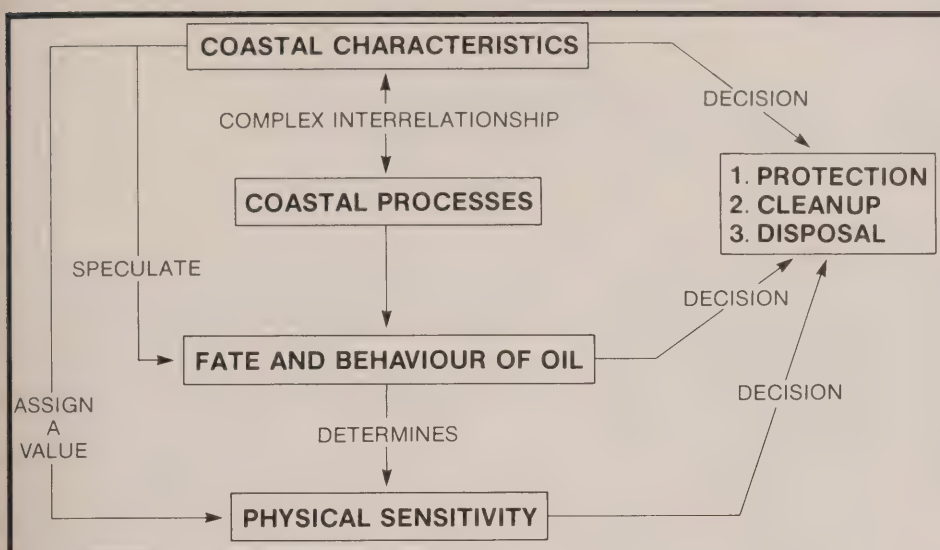
Fjord Sedimentation

Through a recently established program for joint research between the United States Geological Survey and the Geological Survey of Canada (GSC), a cooperative project was undertaken in Kitimat Arm, Dean Channel and Howe Sound involving scientists from the Coastal Studies Institute of Louisiana State University and Texas A&M University. The

aim of the study was to investigate the morphological and geotechnical aspects of large submarine slides on or near fjord deltas. These slides have, in the past, caused considerable damage to shoreline structures and continue to pose a geologic hazard to coastal development. The well-documented slope failure of April 1975, in Kitimat Arm was extensively surveyed using a digital side scan sonar seabed mapping system, a 3.5 kHz sub-bottom profiler, seabed photography and piston and gravity corers. The disturbed sediments from the slide extend more than 4 km down the centre of the inlet, having a volume of approximately $60 \times 10^6 \text{ m}^3$, and in places are up to 25 m thick. (Contact: B. Bornhold.)



Side-scan sonography across the toe of a submarine landslide in Kitimat Arm, B.C., showing contorted marine muds on the right against undisturbed basin sediments on the left. Scale bar is 25 m.



Schematic diagram illustrating the rationale for using coastal geology in oil spill contingency planning. Coastal characteristics as defined by geomorphology and sedimentology must be used to infer active processes which ultimately determine the fate and behaviour of oil. This expected dynamic behaviour of the oil spill along with the physical sensitivity of the coastline provide the basis for decision making.

Coastal Studies

Coastal sedimentology and geomorphology are studied to (i) provide a data base for port location, industrial development, and shoreline management and recreation, (ii) develop oil spill contingency plans including an assessment of the fate and behaviour of oil in the coastal zone and cleanup techniques and, (iii) elucidate the geological evolution of British Columbia's coastline.

To achieve these aims, six locations throughout the Strait of Juan de Fuca, the Gulf Islands and the Strait of Georgia were chosen, each location containing a variety of environments representative of the coast. About 500 sediment samples were collected for sediment textural analysis which, when complete, will provide not only a description of each of the facies encountered in the beach and nearshore zones, but also the basis for understanding the sedimentary dynamics of the coastline. In addition to sampling, beaches and nearshore environments at each location were surveyed, the latter with both an echo sounder and sub-bottom profiler. A SCUBA program enabled first-hand observation of the submarine environments.

These surveys were used to develop a process-response model to describe the evolution of the beach nearshore system within the Strait of Georgia. The nearshore profile develops a characteristic shelf form. The width of the shelf and depth of water at the shelf break increase with exposure to wave energy. Statistical relationships between the wave climate, shelf morphology, and sediment distribution provide a model of the shelf as an equilibrium size-graded form, similar to prograding shelves on the continental margins. (Contact: P. McLaren.)

APPENDIX I

CONTRACTS AWARDED

1981/82

<i>Study of Benthic Community Structure and Dynamics on the Southwestern Continental Shelf of Vancouver Island</i> Dobrocky Seatech Ltd., Sidney, B.C.	\$420,000
<i>Preparation of Oceanographic Data and Scientific Diagrams Using Data from Charts, Tables and Records</i> C. Wallace, Sidney, B.C.	8,044
<i>Numerical Modelling Studies of the Estuarine Circulation in the Strait of Georgia System — Phase III</i> University of British Columbia, Vancouver, B.C. (Dr. R.W. Burling)	19,000
<i>Development of Techniques for Analysis of Lagrangian Oceanographic Data from Drifting Buoys</i> J. Papadakis, Victoria, B.C.	33,350
<i>Oceanographic Observations Aboard C.C.G.S. QUADRA Cruise No. 81-004</i> H. Ashton, Nanaimo, B.C.	6,379
<i>Finite Element Analysis of Storm Surges in the Bay of Bengal</i> CPRO Computing Enterprises Inc., Victoria, B.C. .	27,750
<i>Compilation and Collation of Tsunami Records</i> P. Straub, Sidney, B.C.	1,403
<i>Analysis of Seawater and Marine Air Samples from Weatherships and Other Cruises</i> Seakem Oceanography Limited, Sidney, B.C.	55,828
<i>Zooplankton Sample Collection and Seawater Analysis during Two Research Cruises Conducted by the Institute of Ocean Sciences</i> Broccoli Bros. Enterprises, Sidney, B.C.	3,980
<i>Collection and Compilation of Fraser Estuary and Juan de Fuca Oceanographic Data</i> A. Hartley, Sidney, B.C.	800
<i>Identification of Polychaete on Rock Samples</i> Dobrocky Seatech Ltd., Sidney, B.C.	3,600
<i>Compilation and Appraisal of Existing Physical Oceanographic Data in the Northwest Passage</i> Arctic Sciences Limited, Sidney, B.C.	17,600
<i>Collection of Hydrographic Field Data for Updating and Correction of Navigational Charts</i> Coast Pilot Limited, Sidney, B.C.	90,305

<i>An Intercomparison Study of Magnavox-Hermes AXBT Using the Front Data</i> Interact Computing Services Limited, Victoria, B.C.	1,700
<i>Isotope Dilution Mass Spectrometry Analysis of Seawater Samples from the Alice Arm Area</i> Seakem Oceanography Limited, Sidney, B.C.	4,991
<i>Oceanographic Data Analysis for Alice Arm Mine Tailings Dispersion Study</i> Interact Computing Services Limited, Victoria, B.C.	9,970
<i>Oceanographic Support to the Institute of Ocean Sciences</i> Arctic Sciences Limited, Sidney, B.C.	3,000
<i>Compilation and Filing of Oceanographic Data Collected in Coastal Waters of British Columbia</i> S & B Research Limited, Victoria, B.C.	8,000
<i>Tsunami Data Computer Programming</i> M.M. Nugent, Victoria, B.C.	900
<i>Variability of Winds, Temperature, Humidity and Turbulence with Height</i> Interact Computing Services Limited, Victoria, B.C.	11,680
<i>Role of the Planetary Boundary Layer in Cyclogenesis over the Atmospheric Dynamics Corp., Victoria, B.C.</i>	7,500
<i>Preparation and Drafting of Figures for Marine Meteorology Studies in the Pacific</i> B. Smith, Victoria, B.C.	1,600
<i>Identification and Enumeration of Zooplankton Samples</i> Broccoli Bros. Enterprises Inc., Sidney, B.C.	7,973
<i>Preparation of Data Listings, Maps, Graphs and Data Inventory from Three Cruises</i> B. Smith, Victoria, B.C.	3,910
<i>Study of the Impact of Dumped Mud on Dungeness Crab</i> Archipelago Marine Research, Victoria, B.C.	11,710
<i>Analysis and Interpretation of Atmospheric Carbon Dioxide Data</i> K. Pettit, Unionville, Ontario	1,000
<i>Investigation of Arctic Industrial Offshore Activities and Ocean Dredging and Dumping in British Columbia Coastal Waters</i> R.H. Herlinveaux, Sidney, B.C.	13,575

<i>Analysis of Dissolved Nutrients in Seawater</i> Seakem Oceanography Limited, Sidney, B.C.	8,500	<i>Histological Survey of Mussels from Southern Vancouver Island Waters</i> M.A. Cosson, Brentwood Bay, B.C.	2,100
<i>Oceanographic and Technical Support for the Institute of Ocean Sciences</i> Seakem Oceanography Limited, Sidney, B.C.	3,000	<i>Data Coordination and Management of Precipitation Chemistry Program</i> Interact Computing Services Limited, Sidney, B.C.	8,389
<i>Oceanographic and Technical Support for the Institute of Ocean Sciences</i> Environmental Sciences Ltd., Vancouver, B.C.	3,000	<i>Analysis and Reduction of Data from Alice Arm</i> Interact Computing Services Limited, Sidney, B.C.	22,859
<i>Processing of Data from a Conductivity and Temperature Recorder</i> Interact Computing Services Ltd., Victoria, B.C. .	2,000	<i>Investigation of Structure of Storms and Frontal Systems over the Northeast Pacific Ocean</i> Interact Computing Services Limited, Sidney, B.C.	9,024
<i>Investigation of the Feasibility of Mapping Chlorophyll Concentrations from Space — Phase II</i> University of Western Ontario, London, Ontario	53,070	<i>Compilation and Appraisal of Existing Physical Oceanographic Data in Baffin Bay and the Channels of Ellesmere Island</i> Arctic Sciences Ltd., Sidney, B.C.	22,049
<i>A Physical/Chemical Mass Balance Study for the Beaufort Sea</i> Arctic Laboratories Ltd., Inuvik, N.W.T.	6,020	<i>Development of Computer Programs to Process and Analyse Oceanographic Data</i> Interact Computing Services Limited, Sidney, B.C.	15,007
<i>Study of Solar Stimulated in vivo Fluorescence by Chlorophyll a</i> Seakem Oceanography Ltd., Sidney, B.C.	34,997	<i>Organization of West Coast Ocean Dumping Workshops and Preparation of Annual Report</i> Dobrocky Seatech Ltd., Sidney, B.C.	5,115
<i>Oceanographic Observations Aboard CSS PARIZEAU</i> H. Ashton, Nanaimo, B.C.	1,400	<i>Compilation of Marine Meteorological Data</i> S & B Research Limited, Victoria, B.C.	9,350
<i>Further Development and Modifications to the Model 440 Acoustic Navigation System</i> Mesotech Systems Ltd., North Vancouver, B.C. .	15,000	<i>Development of a Checklist and Up-to-Date Record of Multicellular Non-endoparasitic Marine Invertebrate of the B.C. Coast</i> Khoyatan Marine Laboratory, Cowichan Bay, B.C.	10,000
<i>Evaluation of the Sublethal Effects of Ocean Dumped Material on Benthic Organisms in Alberni Inlet, B.C.</i> Seakem Oceanography Limited, Sidney, B.C. ...	106,684	<i>Development of a Correlation Sonar Current Meter and Ice Movement Detector</i> Caulfield Creative Arts Limited, Sherwood Park, Alberta	977,184
<i>Study of Two-Phase Flow in the Marine Riser of a Subsea Oilwell Blowout Containment System</i> Neotechnology Consulting Ltd, Calgary, Alberta	6,000	<i>Survey of Available Physical Oceanographic Data for the Southern Island Waters of B.C.</i> Arctic Sciences Ltd., Sidney, B.C.	9,876
<i>Development and Application of Computer Program Related to Oceanographic, Thermodynamic and Fluid/Dynamic Data</i> Interact Computing Services, Sidney, B.C.	11,940	<i>Development of Software for the Processing of Bathymetric Data</i> Dobrocky Seatech Ltd., Sidney, B.C.	8,647
<i>Feasibility Study and Trials Associated with the Application of a Dynamic, Self-Powered, Towable Underwater Vehicle to Side Scan Sonar Surveys</i> Sea-I Research Limited, Sidney, B.C.	7,500	<i>Compilation and Collation of Tsunami Records</i> M. Lane, Victoria, B.C.	1,200
<i>Collection of Oceanographic Data Aboard CSS PARIZEAU</i> H. Goldberg, Vancouver, B.C.	1,200	<i>Compilation and Inventory of Beaufort Sea Benthos Data</i> E.V.S. Consultants Ltd., North Vancouver, B.C. ..	8,715
<i>Identification and Enumeration of Marine Phytoplankton</i> E.V.S. Consultants Limited, North Vancouver, B.C.	8,421	<i>Technical Support for the Maintenance and Repair of Oceanographic Equipment</i> Tigyrll Engineering Ltd., Victoria, B.C.	10,000
<i>Evaluation of the Use of Isotope Geochemistry for Tracing Heavy Metals in Marine Systems</i> Seakem Oceanography Limited, Sidney, B.C. ...	157,440	<i>Calibration of Reference Gases of Marine Carbon Research Centre Against World Meteorological Organization Standards</i> University of California, La Jolla, California	5,253
<i>Development and Testing of Sonar Processing Techniques</i> Autonetics Research Associates, Sooke, B.C.	5,000		

<i>On Site Calibration of Marine Carbon Research Centre Infrared Carbon Dioxide Analyzer Against the World Meteorological Organization 1981 Standards</i>	
University of California, La Jolla, California	2,714
<i>Collection of Oceanographic Data Aboard CNAV ENDEAVOUR</i>	
H. Goldberg, Vancouver, B.C.	1,200
<i>Synoptic Aircraft Based Oceanographic Survey of the Arctic Archipelago</i>	
Arctic Sciences Ltd., Sidney, B.C.	128,894
<i>Compilation and Appraisal of Existing Chemical Oceanographic Data in the Northwest Passage</i>	
Arctic Laboratories Limited, Sidney, B.C.	17,550
<i>Preparation of Oceanographic Data and Scientific Diagrams Using Data from Charts, Tables and Records</i>	
C. Wallace, Sidney, B.C.	9,750
<i>Compilation of Arctic Physical and Chemical Oceanographic Data Reports</i>	
Arctic Sciences Limited, Sidney, B.C.	46,772
<i>Development of isolation and separation procedures and histopathological examination of mussels</i>	
Seakem Oceanography Limited, Sidney, B.C.	30,313

<i>Drafting and photographic services</i>	
Techni-Graphics, Victoria, B.C.	4,500
<i>Study of the Measurements of Winds over Coastal Waters by Acoustic Remote Sensing</i>	
Arctic Sciences Limited, Sidney, B.C.	142,257
<i>Statistical Analysis of Survey Data in the Beaufort Sea</i>	
Barrodale Computing Services Limited, Victoria, B.C.	6,000
<i>Study of Plankton-Feeding Alcids</i>	
M. Galbraith, Victoria, B.C.	1,300
<i>Identification and Enumeration of Zooplankton Samples from Alice Arm</i>	
Edward Anderson Marine Sciences, Victoria, B.C.	3,706
<i>Study of Plankton of the Beaufort Sea</i>	
MacLaren Plansearch Inc., Vancouver, B.C.	9,670
<i>Numerical Modelling Studies of the Estuarine Circulation in the Strait of Georgia System — Phase IV</i>	
University of British Columbia, Vancouver, B.C. (Dr. R. Burling)	19,000
<i>The Sedimentation of Mine Tailings in a Marine Environment — Phase I</i>	
Capital Applied Research & Technology Ltd., Victoria, B.C.	38,382

APPENDIX II

PUBLICATIONS

A. Department of Fisheries and Oceans

(1) Pacific Marine Science Reports

PMSR 81-1	Crawford, W.R., and T.R. Osborn	<i>Turbulence in the Equatorial Pacific Ocean</i>
MSR 81-2	Byers, S.C., Dobrocky Seatech Ltd. (ed.)	<i>Report on Ocean Dumping R & D Pacific Region Department of Fisheries and Oceans 1979-80</i>
PMSR 81-3	Whitney, F.A., K. Perry, C. Philpott, A. Ramey, and C.S. Wong	<i>Pentachlorophenol in a Pelagic Marine Ecosystem; Effects on the Ecosystem</i>
PMSR 81-4	Giovando, L.F., and R.H. Herlinveaux	<i>A Discussion of Factors Influencing Dispersion of Pollutants in the Beaufort Sea</i>
PMSR 81-5	Brown, R.E.	<i>Designing, Building and Maintaining the Langara Point Tsunami Warning Station 1968-1980</i>
PMSR 81-6	Giovando, L.F.	<i>Observations of Seawater Temperature and Salinity at Cape Beale Lightstation and Bamfield Marine Station 1969-1977</i>

PMSR 81-7	Papadakis, J.E.	<i>A Simple Method for Monotonic Approximation of Functions</i>
PMSR 81-8	Woodward, M.J.	<i>A Long Life Battery for a One-Quarter Watt Pinger</i>
PMSR 81-9	Papadakis, J.E.	<i>Determination of the Oceanic Wind Mixed Layer Depth by an Extension of Newton's Method</i>
PMSR 81-10	Thomson, Richard E.	<i>An Analysis of Wind and Current Observations Collected in the Queen Charlotte Sound - Hecate Strait - Dixon Entrance Region during 1954 and 1955</i>
PMSR 81-11		<i>Oceanographic Observations at Ocean Station P, 5 January - 15 February, 1979, Volume 97</i>
PMSR 81-12		<i>Oceanographic Observations at Ocean Station P, 9 February - 29 March, 1979, Volume 98</i>
PMSR 81-13		<i>Oceanographic Observations at Ocean Station P, 23 March - 10 May, 1979, Volume 99</i>
PMSR 81-14		<i>Oceanographic Observations at Ocean Station P, 4 May - 21 June, 1979, Volume 100</i>
PMSR 81-15		<i>Oceanographic Observations at Ocean Station P, 15 June - 2 August, 1979, Volume 101</i>
PMSR 81-16		<i>Oceanographic Observations at Ocean Station P, 27 July - 13 September, 1979, Volume 102</i>
PMSR 81-17		<i>Oceanographic Observations at Ocean Station P, 7 September - 25 October, 1979, Volume 103</i>
PMSR 81-18		<i>Oceanographic Observations at Ocean Station P, 19 October - 6 December, 1979, Volume 104</i>
PMSR 81-19		<i>Oceanographic Observations at Ocean Station P, 30 November, 1979 - 17 January, 1980, Volume 105</i>
PMSR 81-20	Thomson, R.E., and W.S. Huggett	<i>Wind-Driven Inertial Oscillations Within Queen Charlotte Sound and Hecate Strait, May-September 1977</i>
PMSR 81-21	Whitney, F.A., C.L. Philpott, H. Seki and C.S. Wong	<i>The Effects of Copper and Copper Plus Glucose on an Enclosed Marine Ecosystem</i>
PMSR 81-22	Huggett, W.S., and M.J. Woodward	<i>Tidal Currents in Johnstone Strait</i>
PMSR 81-23	Giovando, L.F.	<i>Observations of Seawater Temperature and Salinity at British Columbia Shore Stations, 1979</i>

(2) Contractor Report Series

CRS 81-1	Borstad, G.A., and R.M. Brown, Seakem Oceanography Ltd.	<i>Airborne Remote Sensing of Sea Surface Chlorophyll and Temperature Along the Outer British Columbia Coast</i>
CRS 81-2	Brown, R.M., and G.A. Borstad	<i>Canada-France Ocean Optics Experiment: Sea Truth Data for Stations in British Columbia Waters</i>
CRS 81-3	Shearer, Jim, Consultant, Ottawa and Lauchie Meagher, Geomarine Assoc. Ltd., Halifax	<i>Pingo Correlation and Prediction Study</i>
CRS 81-4	Krauel, D.P., Woodward-Clyde Consultants	<i>Deep Water Flow and Exchange Processes in Alice Arm, B.C.</i>

(3) Other Publications, 1981

- AGES, A.B. 1981. Prediction and monitoring oil spills. *Ocean Resources*, Engineering Institute of Canada: pp. 116-119.
- AGES, A.B. 1981. Oil spill modelling — a critique! *Mechanics of Oil Slicks*, Association Internationale de Recherches Hydrauliques, pp. 231-240, Editions Ancien ENPC.
- BACASTOW, R.B., C.D. KEELING, T.P. WHORF and C.S. WONG. 1981 Seasonal amplitude in atmospheric CO₂ concentration at Canadian Weather Station P, 1970-1980. In: *Proceedings WMO/UNEP/ICSU Scientific Conference on Analysis and Interpretation of Atmospheric CO₂ Data*, held September 14-18, 1981, Bern, Switzerland, pp. 163-168. Published by WMO under WCP-14.
- BAKER, H.R. 1981. A redescription of *Tubificoides heterochaetes* (Michaelson) (Oligochaeta, Tubificidae). *Proc. Biol. Soc. Was.* **94**: 564-568.
- BAKER, H.R. 1981. *Phallogrillus tempestatis* n. sp., a new marine tubificid (Annelida, Oligochaeta) from British Columbia. *Can. J. Zool.* **59**: 1475-1478.
- BAKER, H.R. and R.O. BRINKHURST. 1981. A review of the genus *Monopylophorus* and redefinition of the subfamilies Rhyacodrilinae and Branchiurinae (Tubificidae, Oligochaeta). *Can. J. Zool.* **59**: 939-965.
- BOLTON, M. Hydrographic operations in the Beaufort Sea. In: *Proceedings of Colloquium III, Petroleum Mapping and Surveys*.
- BRINKHURST, R.O. 1981. A contribution to the taxonomy of the Tubificinae (Oligochaeta, Tubificidae). *Proc. Biol. Soc. Wash.* **94**: 1048-1067.
- CHAPMAN, P.M. and R.O. BRINKHURST. 1981. Seasonal changes in interstitial sediments and seasonal movements of subtidal benthic invertebrates in the Fraser River estuary. *Est. Coastal Mar. Sci.* **12**: 49-66.
- COATES, K. 1981. New species of *Lumbricillus* (Oligochaeta, Enchytraeidae) from littoral habitats of British Columbia. *Can. J. Zool.* **59**: 1302-1311.
- COATES, K. and D.B. ELLIS. 1981. Taxonomy and distribution of marine Enchytraeidae (Oligochaeta) in British Columbia. *Can. J. Zool.* **59**: 2129-2150.
- CRAWFORD, W.R. and W.S. HUGGETT. 1981. The tidal streams surrounding Vancouver Island. *Lighthouse, Journal of Canadian Hydrographers' Association*, No. 23.
- CRAWFORD, W.R., W.J. RAPATZ and W.S. HUGGETT. 1981. Pressure and temperature measurements on seamounts in the north Pacific. *Marine Geodesy* (5) **1**: 43-53.
- CRAWFORD, W.R. and T.R. OSBORN. 1981. Control of equatorial ocean currents by turbulent dissipation. *Science* (212): 539-540.
- CRETNEY, W.J., R.W. MACDONALD, C.S. WONG, D.R. GREEN, B. WHITEHOUSE and G.G. GEESEY. 1981. Biodegradation of a chemically dispersed crude oil. In: *Proc. 1981 Oil Spill Conference, Atlanta, Georgia, March 2-5*, American Petroleum Institute pub., pp. 37-43.

- CROWLEY, J.V. 1981. Subtense 2. *Lighthouse*, Journal of Canadian Hydrographers' Association No. 23.
- DENMAN, K.L. and J.F.R. GOWER. 1981. Satellite sensed turbulent ocean structure — a reply. *Nature* **794**: 673-674.
- DENMAN, K.L., D.L. MACKAS, H.J. FREELAND, M.J. AUSTIN and S.H. HILL. 1981. Persistent upwelling and mesoscale zones of high productivity off the west coast of Vancouver Island, Canada. In: *Proc. of I.D.O.E. Symposium on Coastal Upwelling*, edited by F.A. Richards.
- FARMER, D. and E. CARMACK. Mixing and restratification in a lake near the temperature of maximum density. *J. Phys. Oceanog.*, November, 1981.
- FARMER, D., A.D. BOOTH and G. KAMITAKAHARA. 1981. Preliminary considerations in the design of a correlation sonar for remote velocity of profiling measurements in the ocean. In: *Acoustic Remote Sensing of the Atmosphere and Ocean*, ed. T. Matthews, University of Calgary.
- FREELAND, H.J. 1981. Book review of *Estuarine and Wetland Processes*, by P. Hamilton and K.B. Macdonald. In: *Transactions of the American Geophysical Union*, EOS, 62(40).
- FRISCH, A.S., J. HOLBROOK and A.B. AGES. 1981. Observations of a summertime reversal in circulation in the Strait of Juan de Fuca. *Journal of Geophysical Research*. Vol. 86, No. C3.
- GARGETT, A.E. and T.R. OSBORN. 1981. Small scale shear measurements during the Fine and Micro-structure Experiment (FAME). *J. Geophys. Res.*, Vol. 86, C3, pp. 1929-1944.
- GARGETT, A.E., P.J. HENDRICKS, T.B. SANFORD, T.R. OSBORN and A.J. WILLIAMS III. 1981. A composite spectrum of vertical shear in the upper ocean. *J. Phys. Oceanog.*, Vol. 11, (9), pp. 1258-1271.
- GARRETT, J. 1981. The performance of the FGGE drifting buoy system. In: *Adv. Space Research*, Vol. 1, pp. 87-89, published by Aberdeen University Press for COSPAR.
- GARRETT, J. 1981. Oceanographic features revealed by the FGGE drifting buoy array. In: *Oceanography from Space*, pp. 61-69. Published by Plenum Press, N.Y.
- GONZALES, F.I., R.A. SHUCHMEN, D.B. ROSS, C.L. ROFENACH and J.F.R. GOWER. 1981. Synthetic aperture radar wave observations during GOASEX. In: *Oceanography from Space*, ed. J.F.R. Gower; Proc. of COSPAR/SCOR/IUCRM Symposium, Venice, Italy, May 26-30, 1980, Marine Science 13, Published by Plenum Press, N.Y.
- GOWER J.F.R. and G. BORSTAD. 1981. Use *in vivo* fluorescence line at 685 nm for remote sensing surveys of chlorophyll *a*. In: *Oceanography from Space*, ed. J.F.R. Gower, Proc. of COSPAR/SCOR/IUCRM Symposium, Venice, Italy, May 26-30, 1980, Marine Science 13. Published by Plenum Press, N.Y.
- GOWER J.F.R. 1981. On the possibility of observing natural chlorophyll *a* fluorescence from space. Presented at the IAMAP general assembly, Hamburg, Germany, August, 1981.
- GOWER J.F.R. 1981. Application of remote sensing to oceanography. Presented at Amagi symposium on remote sensing for oceanography, Amagi, Tokyo, Japan, October, 1981.
- GOWER J.F.R. 1981. Status of satellite remote sensing in oceanography. Presented at Tokyo symposium on oceanographic remote sensing, Tokyo, Japan, October, 1981.
- GOWER J.F.R., Ed. 1981. *Oceanography from Space*. Proc. of COSPAR/SCOR/IUCRM Symposium, Venice, Italy, May, 1980. Plenum Press, Marine Science Series, No. 13, pp. 965.

- HANSON, K.J., J.T. PETERSON, J. NAMIAS, R. BORN and C.S. WONG. 1981. On the influence of Pacific Ocean temperatures on atmospheric carbon dioxide concentration at Ocean Station P. *J. Phys. Oceanog.*, **11**, pp. 905-912.
- HUGGETT, W.S., R.E. THOMSON, M.J. WOODWARD and A.N. DOUGLAS. 1981. *Data Record of Current Observations, Vol. XVIII, Queen Charlotte Sound 1977*, pp. 197.
- HUGGETT, W.S., R.E. THOMSON, M.J. WOODWARD and A.N. DOUGLAS. 1981. *Data Record of Current Observations, Vol. VII, Johnstone Strait*.
- HUGGETT, W.S., R.E. THOMSON, M.J. WOODWARD and A.N. DOUGLAS. 1981. *Data Record of Current Observations, Vol. VIII, Queen Charlotte Sound*.
- ISEKI, K., M. TAKAHASHI, E. BAUERFEIND and C.S. WONG. 1981. Effects of polychlorinated biphenyls (PCBs) on a marine plankton population and sedimentation in controlled ecosystem enclosures. *Mar. Ecol. Prog. Ser.*, **5**, pp. 207-214.
- LEWIS, E.L. and A. POISSON. 1981. Practical salinity scale 1978. *International Marine Science Newsletter*. UNESCO.
- MACDONALD, R.W. 1981. Comments of editorial "Value of an ecosystem" as letter in *Marine Pollution Bulletin*, **12**.
- MACKAS, D., C. BOYD, S. SMITH and H. SANTANDER. 1981. Vertical distributions of plankton in the upper 35 m of the Peruvian upwelling zone. *IMARPE Bulletin*, Special volume, ed., L.M. Dickie.
- MACKAS, D., T. CURRAN and D. SLOAN. 1981. An electronic zooplankton counting and sizing system. *IEEE/MTS Oceans 81*, pp. 738-785.
- MURTY, T.S. and M.I. EL-SABH. 1981. Interaction between storm surges and tides in shallow waters. *J. Marine Geodesy*, Vol. 5, No. 1, pp. 19-34.
- MURTY, T.S., M.I. EL-SABH and J.M. BRIAND. Influence of an ice layer on storm surges amplitudes. *Proc. of the 6th Int. Conf. on Port and Ocean Engineering under Arctic Conditions*, July 27-31, 1981, Quebec, Vol. 1, pp. 415-421.
- MURTY, T.S., M.I. EL-SABH and J.M. BRIAND. 1981. Statistics of extreme storm surges in eastern Canadian water bodies. *Proc. of Oceans 1981 Conference*, September 18-20, 1981, Boston.
- MURTY, T.S. *Seismic Sea Waves-Tsunamis*. Russian translation published by the Soviet Academy of Sciences, Moscow, with a foreword by Prof. A.V. Nekrasov, University of Leningrad, 424 pages.
- O'CONNOR, A.D. 1981. Pavlov's hydrographers. *Lighthouse, Journal of Can. Hydrographers' Association*, No. 24.
- PARSONS, T.R., L.J. ALBRIGHT, F.A. WHITNEY, C.S. WONG and P.J. Le B. WILLIAMS. 1981. The effect of glucose on the productivity of seawater: an experimental approach using controlled aquatic ecosystems. *Mar. Environ. Res.*, **4**, pp. 229-242.
- RICHARDS, D.L. and S.M. MOORHOUSE. 1981. Line passing "Torpedo" for use under sea ice. *Exposure*, a newsletter for ocean technologists, Vol. 9, No. 2, May, 1981.
- SANDILANDS, R.W. 1981. Charting the Beaufort Sea. *Lighthouse, Journal of the Canadian Hydrographers' Association*, No. 24.

- SEKI, H., N. AOSHIMA, F.A. WHITNEY and C.S. WONG. 1981. Microbial readjustment to new balance after influx change of organic material in marine dysphotic layer. *Water, Air and Soil Pollution*, **16**, pp. 331-337.
- SEKI, H., F.A. WHITNEY and C.S. WONG. 1981. Uptake kinetics of dissolved organic matter in a marine ecosystem. *Arch. Hydrobiol.*, **92**.
- STUKAS, V.J. and C.S. WONG. 1981. Stable lead isotopes as a tracer in coastal waters. *Science*, **211**, pp. 1424-1427.
- TABATA, S. 1981. On the accuracy of satellite-observed sea surface temperatures. *Oceanography from Space*, Marine Science 13, ed., J.F.R. Gower, Plenum Press, pp. 145-157.
- THOMPSON, J.A.J. 1981. Production of lead alkyls in marine sediments. *Proceedings of International Conference on Heavy Metals in the Environment*, Amsterdam Netherlands, September, 1981, pp. 653-657.
- THOMSON, R.E. and L.S.C. KUWAHARA. 1981. Detecting temperature fine-structure and mesoscale frontal regimes along line P in the northeastern Pacific Ocean. *Can. J. Fish. Aquatic Sc.*, **38** (1), pp. 40-51.
- THOMPSON, R.E. 1981. Book review of "Descriptive Regional Physical Oceanography," by Ichernia, Pergamon Press, *J. Marine Geodesy*.
- THOMSON, R.E., W.S. HUGGETT and L.S.C. KUWAHARA. 1981. *Data record of current observations*, Vol. XVII, Queen Charlotte Sound — Hecate Strait. Part 1 — Water property observations, May, July and September, 1977, 195 pages; Part 2 — Appendices of water property observations, May, July and September, 1977, 109 pages.
- TOPHAM, D.R. Some environmental problems of under sea oilwell blowouts in Arctic waters. Engineering Inst. of Canada Spring Conference on Ocean Resources, Victoria, March 10-13, 1981.
- TOPHAM, D.R. Modelling of deep oilwell blowout plumes, including the effects of hydrate formation. *Proceedings of the 4th Arctic Marine Oil Spill Program Technical Seminar*, Edmonton, June 16-18, 1981.
- TOPHAM, D.R. A note on the importance of the mechanics of large scale bubble plumes in modelling deep water oilwell blowouts. Workshop on subsea containment of oil, Institute for Environmental Studies, University of Toronto, February 11-12, 1981.
- TUNNICLIFFE, V. 1981. High community diversity and abundance of the epibenthic community of an oxygen deficient basin. *Nature*, November, 1981.
- TUNNICLIFFE, V. 1981. Breakage and propagation of the stony coral *Acropora cervicornis*. *Proc. Nat'l. Acad. Sci.* **78**: pp. 2427-2431.
- WATT, J.V. 1981. Sound velocity display system complements side-scan sonar. *Lighthouse*, J. of Can. Hydrographers' Association, Special Issue, April, 1981.
- WIGEN, S.O. and M.M. WARD. 1981. Post tsunami disaster survey. *Lighthouse*, J. of Can. Hydrographers' Association, Special Issue, April, 1981.
- WONG, C.S., R.D. BELLEGAY and J.S. PAGE. 1981. Seasonal and large-scale variabilities of atmospheric carbon dioxide over the north Pacific Ocean. In: *Proceedings of WMO/UNEP/ICSU Scientific Conference on Analysis and Interpretation of Atmospheric CO₂ Data*; held September 14-18, 1981 at Bern, Switzerland, pp. 43-49. Published by WMO under WCP-14.

WONG, C.S. and K.G. PETTIT. 1981. Global-scale secular CO₂ trends and seasonal changes at Canadian CO₂ stations: Ocean Weather Station P, Sable Island and Alert. In: *Proc. of WMO/UNEP/ICSU Sc. Conf. on Analysis and Interpretation of Atmospheric CO₂ Data*; held September 14-18, 1981 at Bern, Switzerland, pp. 43-49. Pub. by WMO under WCP-14.

B. Department of the Environment Publications

McBEAN, G.A., 1981. Mesoscale features observed from ships. *STREX Workshop Report*, 16-23.

VERMEER, K. 1981. Food and populations of Surf Scoters in British Columbia. *Wildfowl* **32**: 107-116.

VERMEER, K. 1981. The importance of plankton to breeding Cassius Auklets. *J. Plank. Res.*, **3**: 315-329.

C. Department of Energy, Mines and Resources Publications

BARRIE, W.B., J.M. SEMPELS, and P. McLAREN. 1981. Geomorphology. 1980 study results. (BIOS). *Baffin Oil Spill Project working report 80-7*, 200 p.

BORNHOLD, B.D., D.L. TIFFIN and R.G. CURRIE. 1981. Trace metal geochemistry of sediments, northeast Pacific Ocean: *Geol. Surv. Can. Paper 80-25*, 21 p.

CHAN, G.H, H.W. DOSSO and L.K. LAW. 1981. An analogue model study of electromagnetic induction for cape and bay coastlines. *Phys Earth and Planet. Int.*, **27**, pp. 114-121.

CLAYTON, R.W. and G.A. McMECHAN. 1981. Inversion of refraction data by wave field continuation, *Geophysics*, **46**, pp. 860-868.

DeLAURIER, J.M., F.C. PLET and M.H. DRURY. 1981. A geomagnetic depth sounding profile across the northern Yukon and the Mackenzie Delta region, Canada. *Can. J. Earth Sci.*, **18**, pp. 1092-1100.

DRAGERT, H., A. LAMBERT and J. LIARD. 1981. Repeated precise gravity measurements on Vancouver Island, British Columbia. *J. Geophys. Res.*, **86**, pp. 6097-6106.

DRURY, J. and T.J. LEWIS. 1981. Thermal studies in the Lac du Bonnet Batholith at Pinewa, Manitoba. *Tech. Rec. TR-163*, Atomic Energy of Canada.

EDWARDS, R.N., L.K. LAW and J.M. DeLAURIER. 1981. On measuring the electrical conductivity of the oceanic crust by a modified magnetometric resistivity method. *J. Geophysic. Res.*, **86**, pp. 11609-11615.

FUIS, G.S., W.D. MOONEY, J.H. HEALY, G.A. McMECHAN and W.J. LUTTER. 1981. Seismic refraction studies of the Imperial Valley region — profile models a travel time contour map and a gravity model. *U.S. Geological Survey Open File Report 81-270*.

HERZER, R.H. and B.D. BORNHOLD. 1981. Surficial sediments on the continental shelf, southwestern Vancouver Island. *Geol. Surv. Can. Open File 782*.

HYNDMAN, R.D. and G.C. ROGERS. 1981. Seismicity surveys with ocean bottom seismographs off western Canada. *J. Geophys. Res.*, **86**, pp. 3867-3880.

- HYNDMAN, R.D., and R.M. ELLIS. 1981. Queen Charlotte fault zone: microearthquakes from a temporary array of land stations and ocean bottom seismographs. *Can. J. Earth Sci.*, **18**, pp. 776-788.
- HYNDMAN, R.D., M.H. SALISBURY, et al. 1981. Summary of the scientific results of Leg 78B of the Deep Sea Drilling Project. *D.S.D.P. Report*, 282 p.
- IRVING, E. 1981. Phanerozoic continental drift. *Phys. Earth Plan Interiors*, **24**, pp. 197-204.
- IRVING, E. and J.C. McGLYNN. 1981. On the coherence, rotation and palaeolatitude of Laurentia in the Proterozoic. In: *Precambrian Plate Tectonics*, edit. A. Kroner, Elsevier, pp. 561-598.
- LAW, L.K. and J.P. GREENHOUSE. 1981. Geomagnetic variation sounding of the asthenosphere beneath the Juan de Fuca Ridge. *J. of Geophys. Res.*, **86**, pp. 967-978.
- LEWIS, T.J. and G.J. WOODSWORTH. 1981. Heat Generation in the northern Hogen Batholith and nearby plutons of McConnell Creek Map Area, B.C. *Current Research, Part B, Geological Survey of Canada, Paper 81-1B*, pp. 163-164.
- McGLYNN, J.C. and E. IRVING. 1981. Horizontal motions and rotations in the Canadian Shield during the early proterozoic. In: *Proterozoic Basins of Canada*, edit. F.H.A. Campbell, GSC Paper 81-10, pp. 183-190.
- McLAREN, P. 1981. An interpretation of trends in grain size measures. *Journal of Sedimentary Petrology*, **51**, pp. 611-624.
- McLAREN, P. 1981. River and suspended sediment discharge in Byam Channel, Queen Elizabeth Islands, Northwest Territories, Canada. *Arctic*, **34**, pp. 141-146.
- McLAREN, P. 1981. Coastal geology and oil spills. *Episodes*, 1981. pp. 3-8.
- McLAREN, P. Book review of "Sea Ice Processes and Models," Proceedings of the AIDJEX-ICSI (IAHS) Symposium at Seattle, September 1977. IAHS-AISH Publication No. 124: *Arctic*, Vol. 36.
- McLAREN, P., W.B. BARRIE, J.M. SEMPELS, R.A. SEIFFERT, R.B. TAYLOR and R. THOMSON. 1981. Coastal environmental data from eastern Lancaster Sound and northeastern Baffin Island. *Bedford Institute Data Report Series, BI-D-81-1*, p. 281.
- McLAREN, P., W.B. BARRIE and J.M. SEMPELS. 1981. The coastal morphology and sedimentology of Cape Hatt: implications for the Baffin Island Oil Spill Project (BIOS). In: *Current Research, Part B, Geological Survey of Canada, Paper 81-1B*, pp. 153-162.
- McMECHAN, G.A. 1981. Modelling of zero-offset reflection profiles with asymptotic ray theory. *Can. J. Earth Sci.*, **18**, pp. 551-560.
- McMECHAN, G.A. 1981. Mantle P-wave velocity structure beneath Antarctica. *Bull. Seism. Soc. Am.*, **71**, pp. 1061-1074.
- McMECHAN, G.A. and M.J. YEDLIN. 1981. Analysis of dispersive waves by wave field transformation. *Geophysics*, **46**, pp. 869-874.
- MONEL, P. and E. IRVING. 1981. Paleomagnetism and the evolution of Pangea. *J. Geophys. Res.*, **86**, pp.1858-1872.

- MONEL, P., E. IRVING, L. DALY and A. MOUSSINE-POUCHKINE. 1981. Paleomagnetic results from Permian rocks of the northern Schaan crater and nations of the Moroccan Meseta and Pangea. *Earth Plan. Sci. Lett.*, **51**, pp. 65-74.
- REGAN, J. and G.A. McMECHAN. 1981. Ray parameters and focal depths. *J. Phys. Earth*, **29**, pp. 89-95.
- RIDDIHOUGH, R.P. 1981. A global detective story: plate tectonics in western Canada. *GEOS.*, **10**, **4**, pp. 2-5.
- ROBERTSON, P.B. and J.F. SWEENEY. 1981. Haughton impact structure — a terrestrial multi-ring basin? *Lunar and Planet. Sci.*, **12**, Lunar and Planetary Inst., Houston, pp. 894-896.
- ROGERS, G.C. 1981. Geodynamics and seismic risk. *The B.C. Professional Engineer*, **32**, pp. 9-11.
- ROGERS, G.C. 1981. McNaughton Lake seismicity — more evidence for an Anahim hotspot? *Can. J. Earth Sci.*, **18**, pp. 826-828.
- ROGERS, G.C. 1981. Some comments on the seismicity of the northern Puget Sound-Southern Vancouver Island region. In: *Earthquake hazards of the Puget Sound region, Washington State*, edited by J.C. Yount, USGS Open File Report, Menlo Park, California. 21 p.
- SWEENEY, J.F. 1981. Arctic seafloor structure and tectonic evolution. In: *Paleoreconstruction of the Continents*, edit. M.W. McElhinny and D.A. Valencio, Geodynamics Series 2, pp. 55-64.
- SWEENEY, J.F. 1981. Arctic Research for the 1980's, an expose of problems. *Geosci. Can.*, **8**, pp. 162-166.
- WEBER, J.R., J.F. SWEENEY and A.S. JUDGE. 1981. CESAR 83, *Canadian Expedition to study the Alpha Ridge*. Earth Phys. Br., Dept. Energy Mines and Resources, Ottawa, 69 p.
- WEICHERT, D.H. and R.D. HYNDMAN. 1981. A comparison of the rate of seismic activity and several estimates of deformation in the Puget Sound area. In: *Earthquake hazards of the Puget Sound region, Washington State*, edit. J.C. Yount, USGS Open File Report, Menlo Park, California, 21 p.
- YORATH, C.J. and R.L. CHASE. 1981. Tectonic history of the Queen Charlotte Islands and adjacent areas — a model. *Can. J. Earth. Sci.*, **18**, pp. 1717-1739.

APPENDIX III

PERMANENT STAFF, 1981

Institute of Ocean Sciences

A. Department of Fisheries and Oceans

Director-General

Mann, C.R.; B.Sc., M.Sc. (N.Z.), Ph.D. (Brit. Col.), D.Eng. (N.S. Tech.), FRSC

Management Services Division

Chief of Division:

Todd, N.A.; B.Sc. (Glasgow), M.A. (Carleton)

Adamson, G.
*Batchelor, R.J.
*Bell, S.E.
Clapp, L.A.
Coldwell, J.H.
Cooper, B.J.
*Craton, M.I.K.
Curtis, J.N.
Deane, G.J.
Delacretaz, A.
Denney, C.E.
Doxey, K.
Doyle, D.A.
Drysdale, A.E.
Firth, C.
Grills, C.J.
*Hall, E.J.
Keding, L.M.
*Lackner, R.C.
Lafortune, A.J.; B.A. (Manitoba)
*Lalonde, M.T.
Lapp, B.I.; B.A. (Victoria)
Lohrmann, B.A.; B.Sc. (Guelph)
Mathias, A.L.
McKenzie, S.D.
Oakfield, C.L.
Parsons, J.E.
Peirson, E.
Poulin, J.G.

*Reinstein, H.G.
Sabourin, J.T.
*Simington, V.L.
Thomson, L.S.C.; B.A. (Sask), B.L.S. (B.C.)
Tillie, D.G.
Van Dusen, T.S.
Van Eyk, W.J.
*Wonnacott, D.C.

**Left during 1981*

Commissionaires

Sgt. W.L. Caldwell
Sgt. D.W. Price
*Comm. G. Bradshaw
Comm. J. Quinton
Comm. L. Trerice
Comm. P. Osborne
*Comm. J. Stewart
*Comm. G. Armstrong
Comm. H. Moffat
*Comm. J. Selman
*Comm. B. Ashton
Comm. R. Alcock
Comm. J. Redden
Comm. J. Holliger

Personnel

Regional Personnel Manager:

Hamilton, K.R.; B.A. (Brit. Col.)

Knapp, B.M.
Olauson, E.J.
Smith, C.S.
Stevens, I.B.; CIMA (McMaster)
Wenezenki, L.B.

Hydrographic Division

Director of Hydrography

Bolton, M.; C.L.S.

Ages, A.B.; B.A.Sc., M.A.Sc. (Brit. Col.), P.Eng.

**Bastarache, M.; Dip. BCIT

- Bell, R.D.
 *Brown, M.
 *Brown, R.E.
 Browning, P.C.
 *Chan, G.L.
 Chapeskie, R.
 Coldham, F.A.
 Crawford, W.R. B.Sc., M.A.Sc. (Waterloo),
 Ph.D. (Brit. Col.)
 Crowley, J.V.; C.L.S.
 Crowther, W.S.; CC (Ont. Inst. of Chartered
 Cartographers)
 Curran, T.A.; B.A.Sc. (EE), M.Sc. (Brit. Col.),
 P.Eng.
 Czotter, K.L.; Dip. BCIT
 Dobson, D.C.
 Dorosh, L.W.; Dip. BCIT
 Dow, A.J.; P.Eng. (UNB)
 Earl, E.L.P.
 Eaton, G.H.; Dip. BCIT, B.Sc. (UNB)
 Ellison, G.
 Farmer, M.
 Fisher, D.L.
 Galloway, J.L.; B.A.Sc. (EE), M.A.Sc. (EE) (Brit. Col.),
 P.Eng.
 Gould, J.
 *Gregson, D.J.; Dip. BCIT
 Halcro, K.; Dip. BCIT
 Harrison, D.
 Hermiston, F.V.
 Hinds, E.W.; Dip. BCIT
 Hohl, M.
 Hollinger, C.; Dip. BCIT
 Holman, K.R.
 Huggett, W.S.; Master (FG)
 **Jackson, D.
 Jennings, M.
 Johnson, B.A.; Dip. BCIT
 Kenny, B.
 Kidson, G.
 Korhonen, R.K.
 Larkin, J.B.; B.Sc. (PEI)
 Lee, K.S.
 Loschiavo, R.; Dip. BCIT
 Lusk, B.M.; Master, (350 T), C.L.S.
 *Lyngberg, K.; Dip. BCIT
 Lyon, A.G.
 McKenzie, S.D.
 Ma, A.C.; B.Sc. (Victoria)
 *Mikkelsen, M.
 Milner, P.R.; Dip. BCIT
 Moody, A.E.
 Mortimer, A.R.; Master, (FG), B.Sc. (Victoria), C.L.S.
 Muse, R.A.; Trade Cert. CAF
 O'Connor, A.D.; Mate (HT) (U.K.), Master (350T), C.L.S.
 Osborne, M.
 Parks, J.R.; B.A.Sc. (EE) (Brit. Col.)
 Patton, M.M.
 **Pflugger, H.
 Philp, A.R.
 Pickell, L.M.
 Pierce, R.A.
 Pite, H.
 Popejoy, R.D.
 Rapatz, W.J.; B.Sc. (Victoria)
 Raymond, A.R.; Dip. (Algonquin College)
 Richardson, G.E.
 Roberts, J.N.; Master (FG), Cdr. RCN (Ret'd.)
 Ross, A.D.; CC (Ont. Inst. of Chartered Cartographers)
 Sandilands, R.W.; Lt. (H) RN (Ret'd.) FRGS
 Sargent, E.D.; Dip. BCIT
 Schofield, A.
 Smedley, A.J.; LCdr. RCN (Ret'd.)
 ****Smith, G. R.; B.A.Sc. (ME) (Brit. Col.), P. Eng.
 Smith, A.; Master (FG)
 Steeples, J.; Cert. Mech. Eng. (Edinburgh)
 Stephenson, F.E.; B.Sc. (Victoria)
 *Tamasi, C.R.; Dip. BCIT
 Taylor, R.G.
 Taylor, W.R.; Dip. RCC
 **Thompson, A.; Dip. BCIT
 Thompson, L.G.
 Van Duin, W.P.; Dip. BCIT
 Vosburgh, J.A.; Dip. BCIT
 Wakefield, L.M.
 Ward, M.M.; Dip. BCIT, B.A. (Geog.)
 Watt, B.M.
 Watt, J.V.; B.A.Sc. (EE) (Brit. Col.), P.Eng.
 Whincup, G.
 Wigen, S.O.; B.A.Sc. (Brit. Col.), P.Eng.
 ***Woods, M.V.; Dip. BCIT
 Woodward, M.J.; B.Sc. (Victoria), M.Sc. (Toronto)
 Yee, J.
 *Left during 1981
 **Joined during 1981
 ***Educational leave
 ****On Interchange Program

Ship Division

Parkinson, R.W. Engineer 1st Class Combined. Assistant
Marine Superintendent (Engineering). Member, Institute
of Marine Engineers.
Acting Appointment Regional Marine Superintendent

Fitch, L.A.H.; Master H.T.; Assistant Marine Superintendent
(Deck)
Smith, F.V.; Marine & Industrial Electrician;
Depot Supervisor.
Periera, P.; Engineer 1st Class Motor. Relief Chief Engineer
Craton, M.; Administration Clerk

CSS PARIZEAU

Newton, B.L.; Master F.G.; Master
Buchan, J.; Master F.G.; 1st Officer
Butler, K.; Master F.G.; 2nd Officer
Parlmer, S.; Supply Officer
Olcen, P.; Engineer 1st Class Motor, Chief Engineer
Trant, R.; Engineer 3rd Class Motor,
Senior 2nd Engineer
Andersen, A.; Engineer 3rd Class Steam, 4th Class Motor,
2nd Engineer
Stanway, J.D.; Engineer 4th Class Motor, 3rd Engineer
Greening, M.; Engineer 4th Class Motor, 4th Engineer

CSS RICHARDSON

McKenzie, R.; Master H.T.; Master
Burrell, R.; Engineer 4th Class Motor, Chief Engineer

M.V. PANDORA II (Charter)

Jones, R.; Master

CSS VECTOR

Sjoholm, K.; Master F.G.; Master
Wheeler, M.G.; Master H.T.; 1st Officer
Campbell, J.; Mate H.T.; 2nd Officer
Pearson, R.; Engineer 3rd Class Motor,
Chief Engineer
Douglas, D.; Engineer 4th Class Motor,
2nd Engineer

PISCES IV

Chambers, F.J.; Chief Pilot
Taylor, R.H.; Pilot
Witcombe, A.; Pilot
Oszust, J.; Pilot
Thomas, G.; Pilot
Shepherd, K.; Pilot

Ocean Information

Chief of Division:

Cornford, A.B.; B.Sc. (McMaster), Ph.D. (Brit. Col.)

Smiley, B.D.; B.Sc., M.Sc. (Alberta)

Ocean Chemistry Division

Chief of Division:

Wong, C.S.; B.Sc., M.Sc. (Hong Kong), Ph.D. (Scripps),
Dip. Mar. Sc. (UNESCO), FRSC (U.K.)

Bellegay, R.D.; Dip. NAIT, Assoc. Deg. in Oceanography
(Shoreline Community College, Seattle)

Cretney, W.J.; B.Sc., Ph.D. (Brit. Col.)

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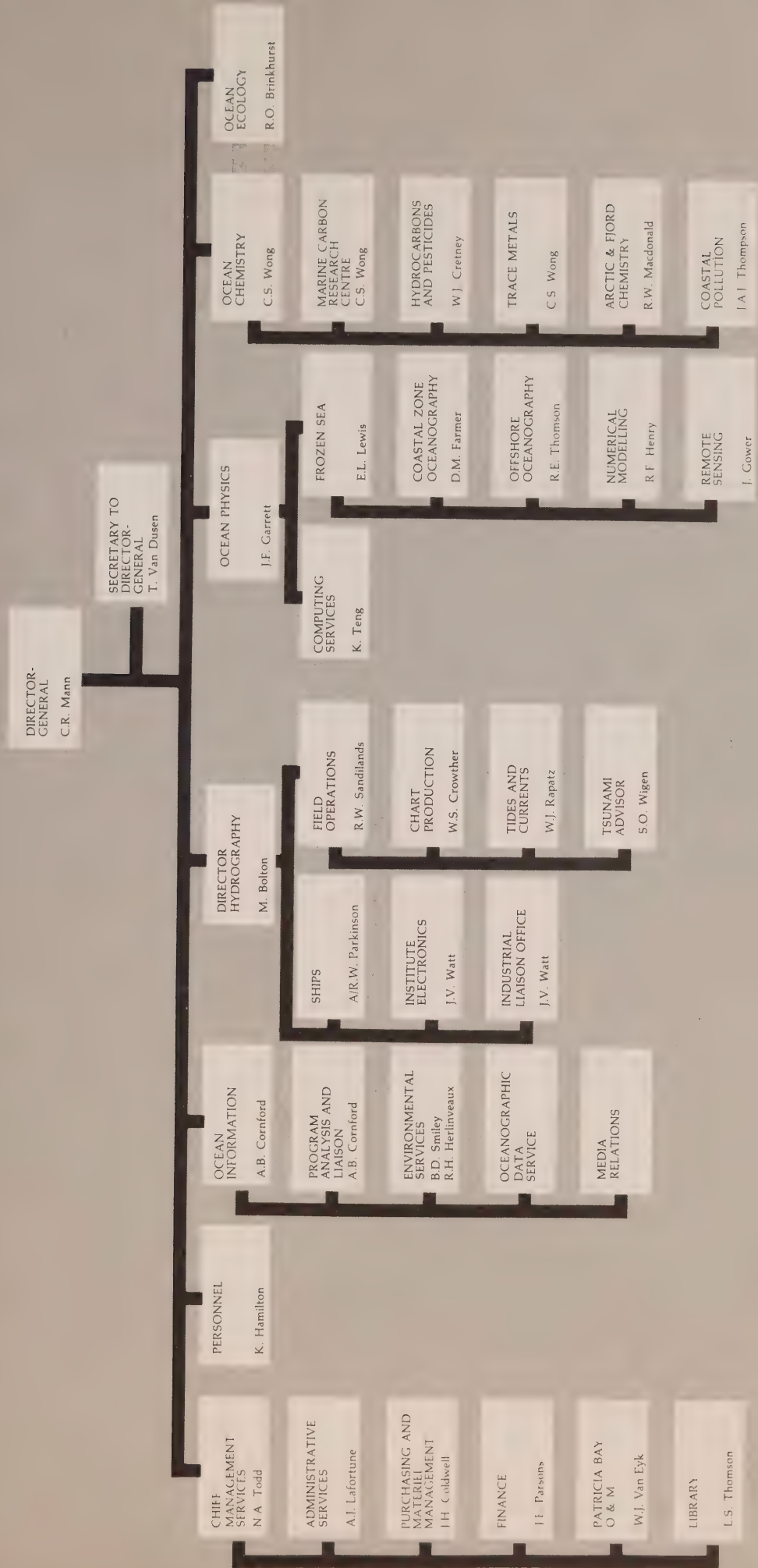
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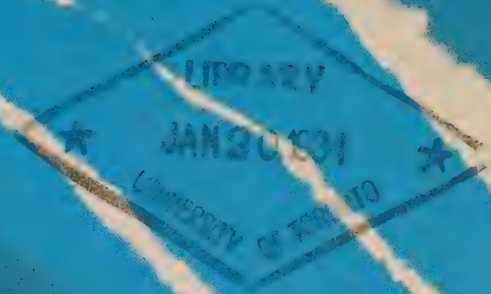


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1982
ANNUAL REVIEW
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Institute of Ocean Sciences
PATRICIA BAY, SIDNEY, B.C.



Government of Canada Gouvernement du Canada

Fs 1-26/1982E

ISBN 0-662-12551-7

For additional copies or further information, please write to:

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DEPARTMENT OF FISHERIES AND OCEANS

Director-General's Foreword

This year saw steady progress in hydrographic and oceanographic projects that had been initiated over the past few years. The work on charting a safe corridor for navigation through the Beaufort Sea, and on the assessment of the impact on the ocean environment of the molybdenum mine in Alice Arm, has gone very well. The charter vessel *Polar Circle* continued the survey of the Beaufort Sea corridor which is now 86% completed and should be finished next year. A major part of the field work for the Alice Arm project has been completed as planned. The field program will be finished in 1983 and a start made on the interpretation of the data. The Arctic continues to be an area of high priority to which we devote a considerable proportion of our resources. In addition to the hydrographic survey in the Beaufort Sea our Tides and Currents Section has expanded its tidal and current survey in the western Arctic and scientists in the Frozen Sea Research group are well into a major study of currents in the Canadian Arctic Archipelago as well as continuing their studies in the Arctic Ocean.

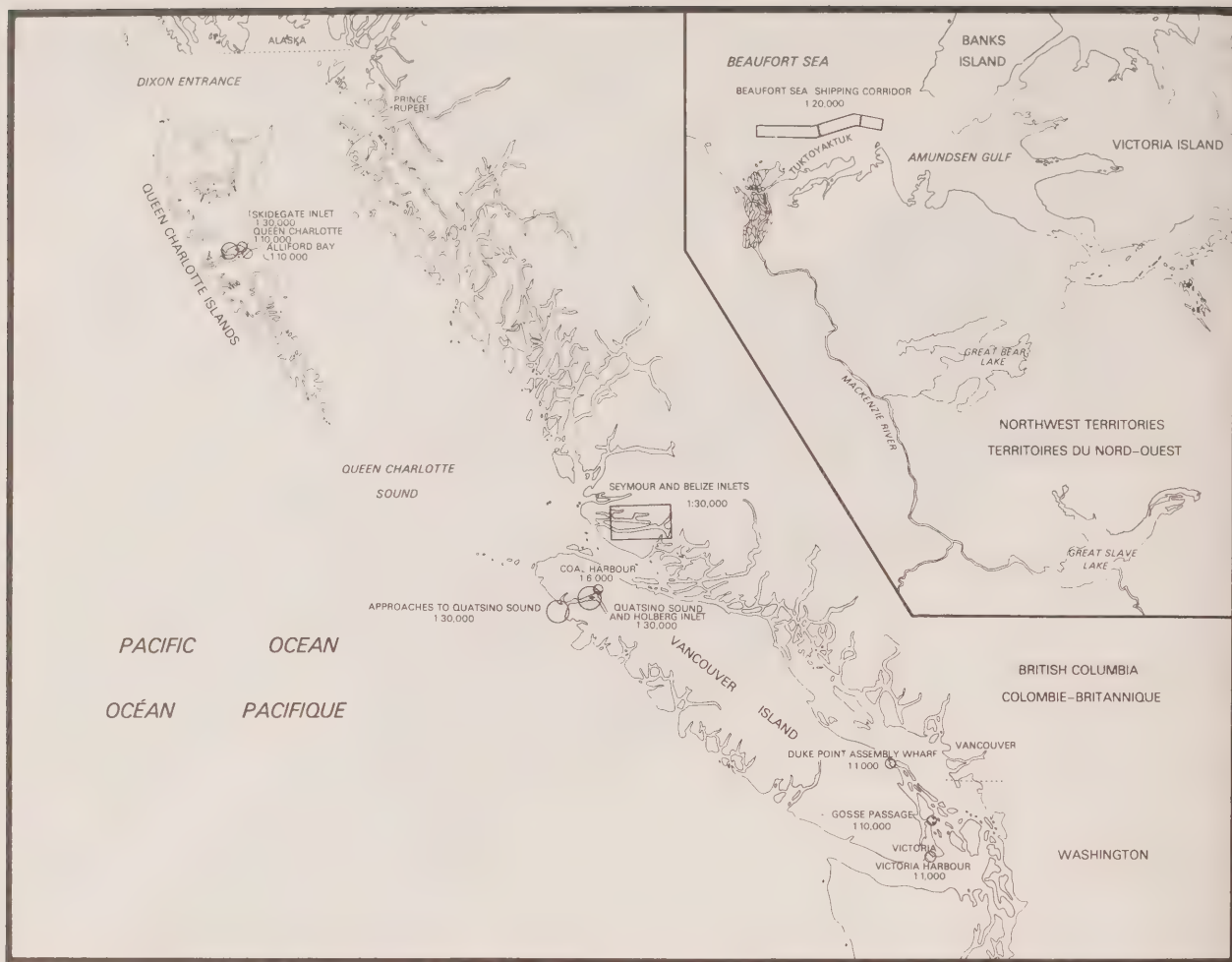
The programs in Ocean Information Services, Chemistry, and Ecology also acquired more substance this year due to past efforts. Ocean Information Services has published the first of a series of documents assessing and cataloguing all oceanographic data in the Arctic and west coast. One outcome of this effort has been that a great deal of data has been discovered that was not in the archives of the Marine Environment Data Service. We have also spent considerable effort reviewing EIS's and on advice regarding environmental problems. Chemistry and Ecology have made good use of the contracting process to expand their research. A large part of the benthic program is done by contract and in collaboration with the University of Victoria. Similarly much of the CO₂ and seaflux programs is accomplished by contract and in collaboration with scientists from other laboratories.

It is worth remarking that the use of acoustic transmission as a tool in oceanography has attracted oceanographers for many years. In the last few years interest in use of acoustic techniques has been renewed, experiments in acoustic tomography have been conducted by the United States over hundreds of kilometres of ocean which have proven successful. To work on this scale is beyond the means of IOS, however, we have several developmental, and novel, acoustic projects which add up to a very respectable program and which are described later in the report. It is our intention to continue with this effort in acoustics as it does promise to enable measurements which cannot readily be made by other means.

One of the difficulties in writing this foreword has been to pick out of our program items which merit special attention, a task that was really not possible this year. What follows is a description of some of the many areas in which progress has been made.



Hydrography



Pacific Region 1982 hydrographic survey program.

The Hydrographic Division continued to pursue its main objective which is the provision of current navigational information in the form of nautical charts, sailing directions and tidal and current tables. An extensive network of chart dealers is employed to disseminate these publications to the various commercial and recreational users.

Emphasis was placed, as in 1981, on continuing surveys of a navigational corridor through the Beaufort Sea, along with resurveys and revisory surveys of the Pacific Coast. A new small craft chart covering the mainland coast from Vancouver Harbour to Desolation Sound was published, and well received by the boating public. As well as conducting major current surveys in the Queen Charlotte Sound area, a long term circulation and mean sea level study was commenced in the western Arctic.

Two senior staff left during the year to join the private sector: J.V. Watt, Head of Engineering Services and A.D. O'Connor, Senior Field Hydrographer. Their enthusiasm and experience will be missed, however, this is perhaps, the most effective method of transferring technology from government to industry.

Ship Division continued to provide support to OSS Pacific programs, to other federal government departments and to Canadian west coast universities. In November, CSS *Parizeau* commenced her mid-life refit. Major modifications include engine and generator replacements plus additional enhanced accommodation for ships' personnel.

Field Hydrography

The Field Hydrography Section is responsible for conducting hydrographic surveys of the B.C. coast, western Arctic, and navigable inland waters of the Pacific Region in order to ensure that requirements for navigational information are met. Alterations of, and additions to, traffic routes, types and sizes of vessels, harbours, bottom topography and coastlines — all require an ongoing survey and resurvey program.

The major coastal survey party was assigned to the barge *Pender* from April to October. A survey of the previously uncharted Seymour, Belize and Nugent waterway complex was completed. At present this area is only covered by reconnaissance surveys made by the British Admiralty over one hundred years ago. The party completed their season with a resurvey of Holberg and Rupert Inlets and portions of Quatsino and Neroutsos Inlet to modern standards. (Contact: G.E. Richardson.)

CSS *Richardson* provided logistical support to a second coastal party which completed the ongoing resurvey of Skidegate Inlet in the Queen Charlotte Islands.

Later in the season this ship and party commenced surveys of portions of the approaches to Quatsino Inlet which were required at a larger scale necessitated by new chart scheming. (Contact: J.V. Crowley.)

The charter vessel *Polar Circle* continued the survey of a deep-draught shipping corridor through the Beaufort Sea. This corridor is 10 nautical miles (nm) wide and approximately 170 nm in length and runs through an area known to contain Pingo-Like-Features (PLFs). This survey was commenced by CSS *Hudson* last year and is now approximately 86% sounded with completion expected next year given reasonable ice conditions. (Contact: J.A. Vosburgh.)



Launch BOLD at high speed in Beaufort Sea.

Several small local revisory survey projects based at IOS were carried out during the summer and a complete resurvey of James Bay, Victoria Harbour was carried out after the return of the major parties from their scheduled projects. This survey which was not on our program but requested by the Department of National Defence (DND), was necessitated by the Royal visit to Victoria, scheduled for March 1983, which entails berthing the H.M.Y. *Britannia* at Ship Point Wharf in the Inner Harbour. (Contact: B.M. Lusk.)

The Navigation Group continued Loran-C calibration work. This year's efforts were directed towards the approaches to Prince Rupert where an increase in shipping is expected. An evaluation of ultra-high frequency positioning systems was undertaken in conjunction with Atlantic Region's Navigation Group. These systems appear to have several potential applications to hydrography.

In mid-September the region's Navigation Group carried out further monitoring of the Loran-C patterns in the southern Vancouver Island area. These investigations will supply correct time delays and more accurate propagation information for new, latticed charts in southern areas. Early in the year, this same group carried out Accufix/Loran-C investigations in the western Arctic to assist future navigation. (Contact: A.R. Mortimer)

Surveys for chart and Sailing Directions revisions were carried out under contract.

Removing ARGO site from Baillie Island.



Sailing Directions

The Twelfth Edition of the *British Columbia Coast Sailing Directions (South Portion)*, Volume I, was published in June. This edition includes new information on tidal streams, seabed, vessel traffic management, Loran-C, search and rescue, regulations and port facilities. The chapters covering the Gulf Islands and south portion of the Strait of Georgia were rewritten to conform with new metric charts published for this area in recent years. New photography and several new diagrams were incorporated into this edition. Volume II (North Portion) and Volume I are published in alternate years. (Contact: Volume I, A. Smith; Volume II, J. Roberts.)

The Fourth Edition of *Small Craft Guide, Volume II, Boundary Bay to Cortes Island*, was also published in June. This edition contains extensive revisions and new photography for the Fraser River and Vancouver Harbour. A new edition of the companion, Volume I, Port Alberni to Campbell River will be published in 1983. (Contact: L.M. Wakefield.)

Hydrographic Development

Only minor changes in software were necessary to send the PDP-11 computer system to the Beaufort Sea on board MV *Polar Circle* for another successful season.

Due to the difficulty experienced last year in producing final field sheet plots, a contract was let to rewrite this package to improve the data handling routines, and facilitate user interaction with the program. The basic overplot-removal algorithm was retained. As a result, this year's data were plotted quickly and adequately with minimum frustration.

As a spin-off from the Sterntow Project, a new data logger has evolved to replace PHAS (portable hydrographic acquisition system). A contract has been let to extensively modify the existing PHAS processing software. This will be completed and tested prior to the 1983 field season.



Chart Production and Distribution

There are two main functions of Chart Production and Distribution: to process survey and other data into new or existing charts and publications as quickly as possible, and to ensure that an adequate stock of corrected charts is readily available for all users of Canada's navigable waters.

In addition to chart and publication production and distribution, there is also an on-going education and promotion program, including tours, displays and lectures, aimed mainly at colleges and marine organizations. In 1982, this included participation in the Vancouver Boat Show. Two newsletters and five news releases were issued in 1982, announcing new charts and publications, and a total of 186,000 charts and 69,000 publications were distributed.

Cartographic training continued for production staff in 1982 with four junior cartographers attending the Carto I course and two senior cartographers attending the Carto II course, and four cartographers assisted in hydrographic surveys for periods varying from three weeks to three months.

Nineteen eighty-two was a very busy year in automated cartography. The system was heavily loaded with digitizing, editing and data processing. A VAX-11/750 minicomputer system was ordered to provide another graphics work station and which will support up to three stations if required in future.

The RK07 disc drive installed in early 1982 has proven to be very useful since it permits cartographers to digitize one file and edit another file simultaneously. Also, program maintenance and development can now proceed at the same time.

GOMADS (on-line editing and compilation) software was modified to use the old Talos digitizing table as an accurate pointer. It is not yet clear whether the table has sufficient accuracy to permit inputting new information from a graphic. Also during

1982, the production of the Pacific Coast Chart Catalogue was partially automated allowing cartographers to enter the chart limits into a data file and then produce the chart catalogue from it.

All the digital data for chart set 3311 is now ready for entry into the Digital Data Library. The computer-assisted drafting system lends itself well to charts with overlapping areas and with data displayed in several different orientations. Other charts currently in-hand for computer assistance are 3544, 3461, 3462, 3463 and 3527.

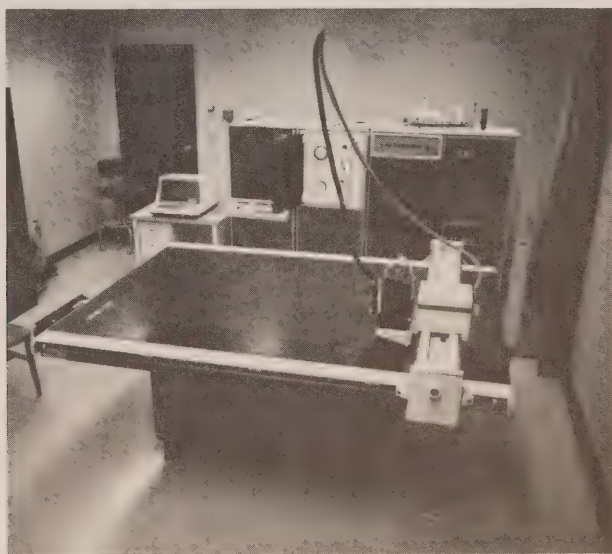
An OVAAC-8 image processing system including an Ikonas display processor, an Imapro colour hardcopy unit, a Century Data 300M byte disc drive, a 1600 bpi mag tape drive, and a small GTCO digitizing tablet, installed on the PDP-11, is now being used by the Chart Production section.

The Chart Distribution office has converted from a key punch card method of data input to a more efficient method by using a Radio Shack TRS80 computer. Data is then transmitted to the Univac System.

On-site inspections of twenty-three dealerships were conducted to ensure adherence to standards. Thirty-nine new dealerships were awarded and twenty-five dealerships were cancelled.

The chart inventory and control system was recently revised to allow for long-range (5 year) planning. This system has proved beneficial in assessing quantities of charts to be stockpiled for specific periods. In addition to the cyclical printing program, which was initiated a few years ago, the production of overprints and 'no date' patches has greatly assisted in reducing the amount of hand amendments required.

Kongsberg Plotter





Tidal and Current Surveys



This program provides tidal, current and water level data, along with other information and expertise, for the Canadian west coast and western Arctic. A permanent and temporary tidal gauging network is maintained for operational and research purposes.

In the western Arctic, a one-month tidal and current survey was carried out in Amundsen Gulf and southern Prince of Wales Strait. Six tide gauges and one current meter were placed and recovered. Data return was excellent. A multi-year program to measure long-term mean sea level variations in waters contiguous to the Arctic archipelago was begun by placing tide gauges in five locations on the outer coast.



Installing a tide gauge through the ice at Isachsen.

In April of 1982 direct responsibility for permanent tide gauges in the western Arctic was assumed by the Tides and Currents Section. (Contact: F.E. Stephenson.)

Major current surveys were carried out in Queen Charlotte Sound and in Chatham Sound near Prince Rupert. Twelve moorings were laid in May and recovered in September. Data reduction, analysis and interpretation is now being carried out.

Inspection, maintenance and operation of several temporary tide gauges and two tsunami warning gauges are being carried out on an on-going basis. Data from these gauges, as well as data from 17 permanent tide gauges operated by Water Survey of Canada, are reduced, analysed and sent to MEDS (Marine Environmental

Data Service) on a routine basis. Tidal Acquisition and Telemetry System (TATS) gauges have now been installed in Victoria, Point Atkinson and Vancouver Harbour and a radio repeating tide gauge was installed in the Vancouver Harbour Master's office.

Final tests were carried out to confirm the usefulness of an oil-spill tracking technique developed in this section. A report on this technique was published. (Contact: A. Ages.)



An oil spill marker, developed at IOS, can be "parachuted" to a spill site and then tracked electronically as it moves on the water's surface with the oil.

A computer model study of the movement of industrial waste and sewage in the Fraser River estuary was conducted as part of the Federal-Provincial Aquatic Environmental Monitoring Committee program. As a participant on the Environmental Emergency Working Group in the Greater Victoria area, Tides and Currents Section assisted in the preparation of oil spill counter-measures and participated in the prediction and monitoring of two minor oil spills in B.C. coastal waters.

Field and model studies of tides, currents, salinities and temperatures in the Fraser River were continued. The private sector and various government agencies were provided with information and advice on water movement in the Fraser River.

Diving Unit

Diving activity was reduced slightly in 1982, with approximately 100 dives being logged during the year. The number of users of diving services and the variety of tasks performed was about the same as in previous years.

Divers examined various parts of the *Parizeau* and *Pandora II*, observed prototype samplers and release systems in operation, and worked with sediment traps, current moorings and wave measuring equipment. As in previous years many of the dives involved either the installation or recovery of pressure gauges. Major projects in this regard were in Queen Charlotte Sound, Alice Arm and the western Arctic. Closer to home, many dives were also done at the enclosed ocean experiment (CEPEX) site in Patricia Bay.



A replacement current meter is secured to mooring (10 m) at Race Rocks.

Tsunamis

Investigations during 1982 showed that a number of delta fronts in coastal inlets have a history of slumping. Tsunami waves created by these submarine landslides can destroy docks and damage ships and boats. A detailed study is in progress of unusual ridges of the lower slopes of the Fraser Delta, that may have originated from such a sudden massive landslide. Information is being sought on the frequency of occurrence of such events.

The historical study of tsunamis for Canadian west coast ports is continuing. Tsunamigrams from analogue tide records are being systematically digitized.

Spectral analysis routines are being developed to study both the energy distribution of particular tsunamis, and the response characteristics of tide stations. Such studies will provide new information to forecast the tsunami hazards at coastal locations. The study is being coordinated with similar work in other Pacific Rim countries, as part of Canada's contribution to the International Tsunami Warning System.

The Tsunami Unit of IOS is participating with the International Tsunami Information Center (ITIC) in the development of a master plan for the Tsunami Warning System, and in planning for regional warning centres. Warning procedures for Canada's west coast are being developed and coordinated through the B.C. Earthquake and Tsunami Working Group. (Contact: S.O Wigen.)

Engineering Services

Engineering Services provides electronic and mechanical engineering, electronics support for hydrographic surveys, oceanographic research and ship operations and an industrial liaison service promoting liaison between IOS and the private sector. (Contact: T.A. Curran.)

Engineering Development

This service includes custom development of instrument systems, contract management of government funded private sector developments, and ongoing electronic/mechanical consultations to all IOS groups.

During 1980 a feasibility study to examine the means by which the rate and direction of drifting buoys could be controlled was undertaken. From this study, the concept of active drifters was developed, and subsequently, testing to demonstrate the concept using solar power was initiated. Dynamics of the sterntow system were successfully tested. This hydrographic survey package, supported by the High Arctic Research Program (HARP) will produce two to four sounding lines in addition to the ship's track. Fabrication and machining projects included an ice hole melter, various pressure cases, a 20-bottle motorized incubation rack, a gearbox for the "salinity sucker", specialized teflon "bombs" used in chemical analysis, and numerous repairs and modifications to existing prototype equipment.

Many significant electronics projects and project phases were completed during 1982. A multi-channel frequency counter for measuring environmental parameters was completed and applied in the field. A self-contained Aanderaa data tape translator with industry standard RS232 ASCII output was designed, constructed and successfully tested. A similar project was the implementation of a microcomputer-based multi-purpose parallel to serial RS232 ASCII converter. Refinements to Arctic survey launch navigation control were implemented to facilitate use with ARGO positioning equipment in the Beaufort Sea as part of continuing HARP support. Optimization of the acoustic Doppler current meter electronics yielded improved system range, resolution and stability. A portable acoustic Doppler recording system

was developed for use with commercial sounders. A computer system for data acquisition of stern-tow survey data was assembled and the software completed under contract. The first phase of a Correlation Sonar contract was successfully completed, demonstrating the practical feasibility of measurement of ocean current velocity and ship speed using acoustic remote sensing techniques. Other contract management activity included a ships-of-opportunity temperature and conductivity recorder. (Contact: J.L. Galloway.)

Electronics Technology Support

Technical support group activities were directed toward normal maintenance programs involving IOS vessel equipment and equipment used by hydrographic personnel. A major emphasis in 1982 was the planning, installation and field support for electronic survey equipment on the *Polar Circle's* western Arctic hydrographic survey. West coast surveys with vessels *Pender*, *Richardson* and associated launches also required technical support. Other staff activities included equipment acquisition, evaluations, modifications, and installations. A remote radio and antenna controller for the IOS radio base station, manufactured under contract, was installed late in the year. A method of improving radio communication during marginal or poor conditions is under study and field evaluations are planned for 1983. Numerous modifications and improvements to commercial survey equipment were implemented. (Contact: W.R. Taylor.)

Industrial Liaison and Contracting

The Institute of Ocean Sciences has an established policy of conducting a significant portion of its program through contracts to the private sector. Liaison and support for contracting activities is conducted by the administrative staff of the Engineering Services Group.


In addition to contracting out directly, IOS participates in such government ventures as the Unsolicited Proposals (UP) program with the Department of Supply and Services (DSS), and both the Program for Industry/Laboratory Projects (PILP) and the Industrial Research Assistance Program (IRAP) with the National Research Council (NRC). IOS was involved to some extent in 92 contracts in the past year, ranging in value from less than one thousand dollars to approximately one million dollars, and with a total value in excess of \$5 million.

The UP program has been especially successful at IOS. Ideas for research and development work, originating in the private sector, are submitted to DSS for funding. IOS often sponsors proposals directly affecting its mandate. Proposals must have scientific merit and be clearly unique to justify the waiving of the normal competitive process. Any resulting hardware, software or intellectual rights remain with the Crown.

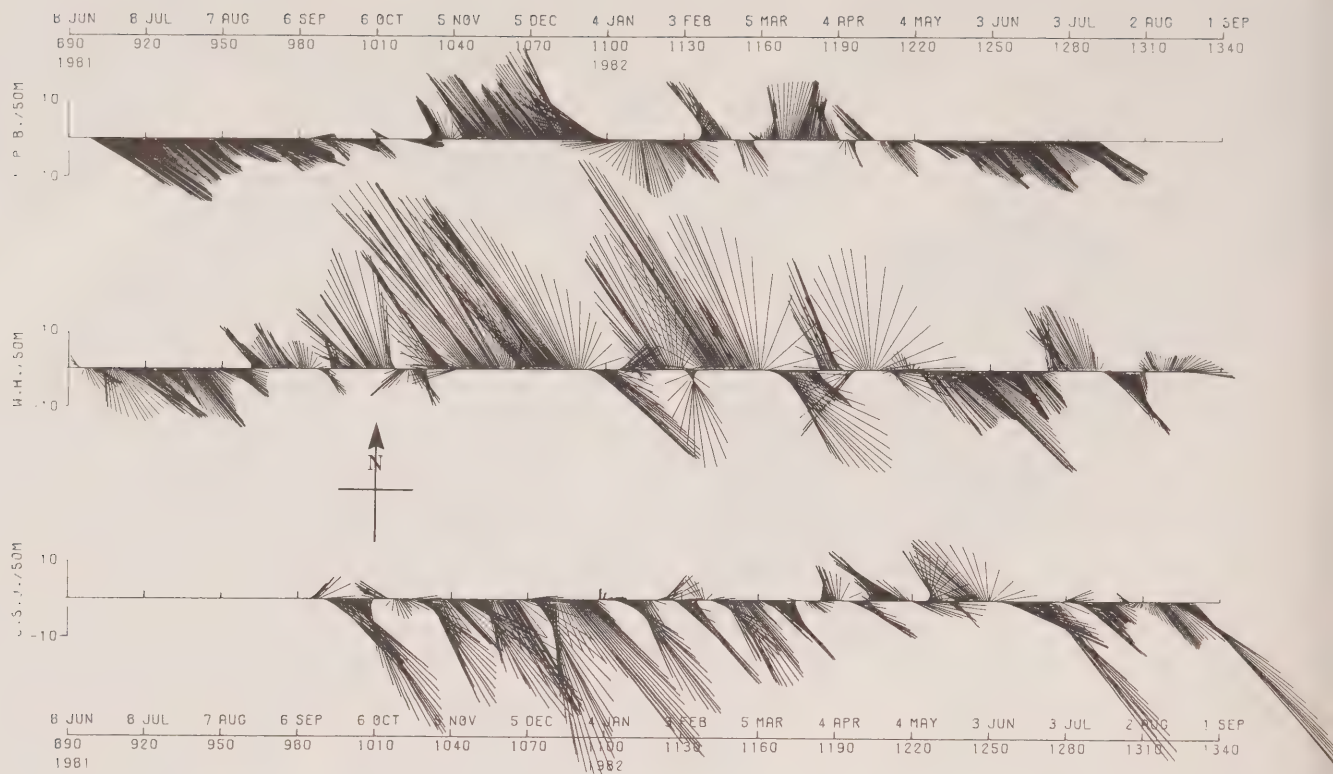
During the past year, there was one successful PILP, and others in the development stage. This NRC program provides financial assistance to companies to

enable the fruits of government research to reach the marketplace. Under this program, reasonable rights are normally transferred to the participating company under arrangement with the Crown. IOS benefits indirectly by being able to purchase commercial equipment and support.

Another NRC program, IRAP, funds salaries of research professionals to assist small and medium-sized companies to develop commercially-viable products. There was one successful award during the past year to a company performing research of interest to IOS, and other submissions may be upcoming.



Oceanography



Near surface current meter vectors at three locations off the west coast. The locations are (from the top): southern Vancouver Island, northern Vancouver Island and southern Queen Charlotte Islands. On dates, marked below and above the data, the direction of the current flow is given by the direction of the stick and speed, by the length of the stick. Features to note are: the general lack of similarity between different sites, the unusual pulsing of the Cape St. James current with a period of 12 days, and the annual cycles at the two sites bracketing Queen Charlotte Sound are almost exactly 180° out of phase.

The oceanographic program at IOS includes ocean physics, ocean chemistry and ocean ecology. The oceanographic information on current systems and associated temperatures and salinities, on the chemistry of the ocean and associated pollutants, and on primary productivity and the lower trophic levels of the food chain, such as plankton, are provided to agencies engaged in environmental protection, to fisheries managers, to industrial concerns, defence, and to others who have a need for information about the oceans.

Ocean Physics ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

This year saw the scientists of the Ocean Physics Division engaged in a broad spectrum of activities. Major observational programs were conducted in the Northwest Passage, along the B.C. coast as far north as the Queen Charlotte Islands, and in Observatory Inlet. Other field work included a cooperative study of the oceanography of the Great Barrier Reef, and a survey of McMurdo Sound to examine the effect of supercooling by the Ross Ice Shelf on surrounding water masses. The interpretation of data from earlier observations and associated development of theories and models continued at a frantic pace. One interesting activity has been the involvement of IOS scientists in international efforts to improve storm surge forecasting in the Bay of Bengal, as affecting Bangladesh.

The most important change was the arrival of two new scientists to work on theoretical aspects of general ocean circulation and the role of the ocean in climate dynamics. This will significantly increase overall Canadian activity in this area of current concern, and will permit the oceanographic community to respond more effectively to the needs of meteorologists studying climate variability.

Coastal Zone Oceanography ☐☐☐☐☐☐☐☐☐☐

Analysis of data collected on the southern Vancouver Island Continental Shelf continued during 1982 in conjunction with the Ocean Ecology Division. A description of the statistical structure of oceanographic fields on a continental shelf is emerging that is internally consistent with the known dynamical structure of those fields. This will permit the development of an internally consistent set of covariance functions which in turn will facilitate the problem of the mapping of oceanographic fields in an objective manner. (*Contact: H.J. Freeland.*)

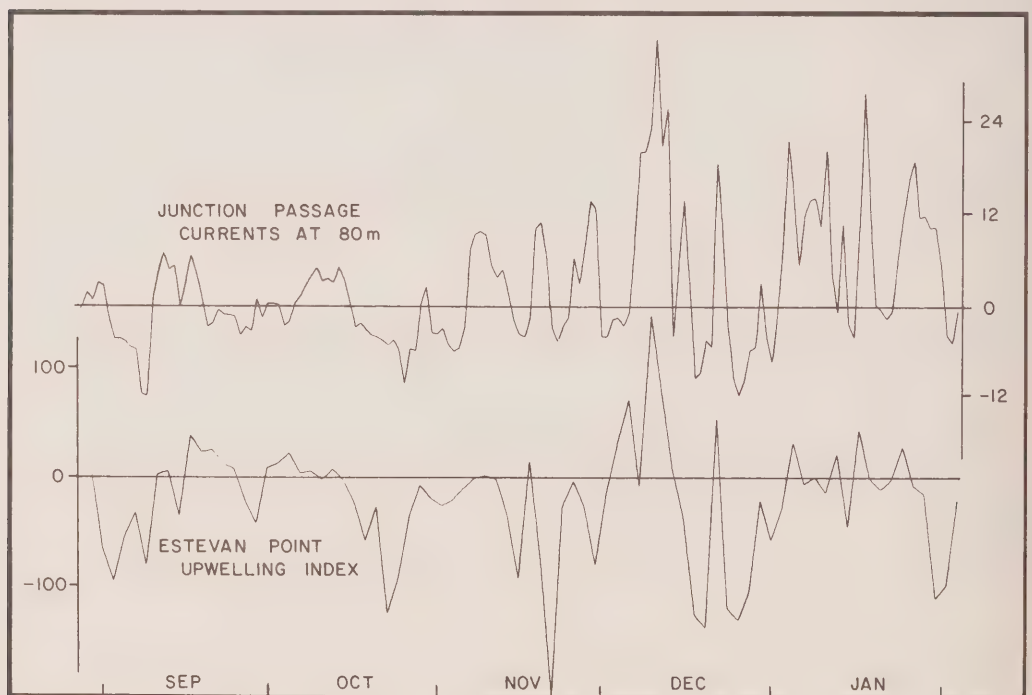
During 1982 the contribution to SUPERCODE was terminated after 1½ years. The total data return rate from moorings during this experiment was 96.1%.

SUPERCODE was a large international experiment to search for low frequency signals propagating along the continental shelf wave-guide. Preliminary investigation

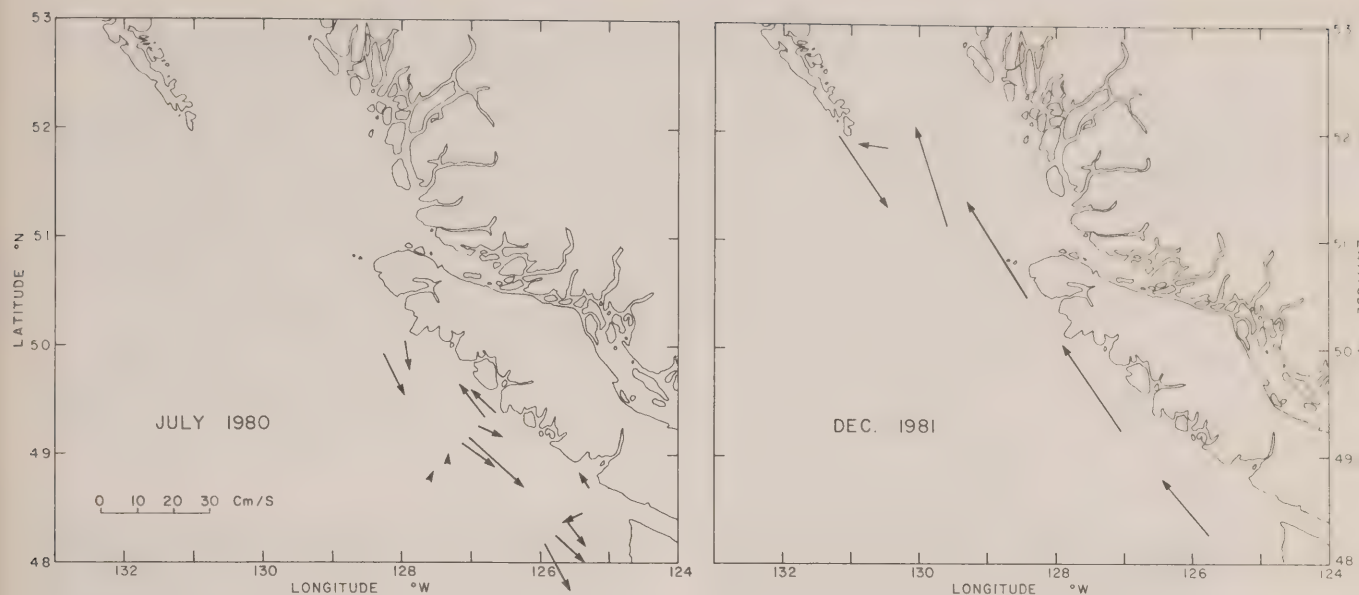
indicates a number of surprising features some of which are illustrated in the current meter "stick-plot" shown here. Even though the southernmost Canadian mooring shows substantial coherence with a mooring off Crescent City (N. California), all coherence appears to be lost over the next 200 km along the west coast of Vancouver Island. The current field off Cape St. James (west coast of the Queen Charlotte Islands) shows a current system qualitatively different from that observed anywhere else. It is hard to see what physical processes can be acting to produce such radically different flow patterns over such short along-shore displacements.

Despite this apparent lack of order, a large-scale overview of the circulation off the west coast of B.C. is emerging as a result of the various large programs carried out by the Coastal Zone, Offshore Oceanography and Tides and Current Survey groups over the past 4 years. We are developing a picture of a current which we have named the Vancouver Island Coastal Current which appears to show remarkable similarities to the Norwegian and Alaska Coastal Currents. (Contact: H.J. Freeland.)

Studies of fjord circulation continued with preparation of a review of the physical oceanography of fjords and analysis of shear flow instabilities in the vicinity of sills. In response to concern over mine tailings disposal problems, field effort shifted from Knight Inlet to Observatory Inlet and Alice Arm. Analysis of the estuarine circulation in Alice Arm, based on the daily time series of CTD observations taken during the summer of 1981, has shown that there is little relationship between local run-off and



Low passed inflow/outflow currents measured near Junction Passage and upwelling index calculated from Estevan Point wind data.

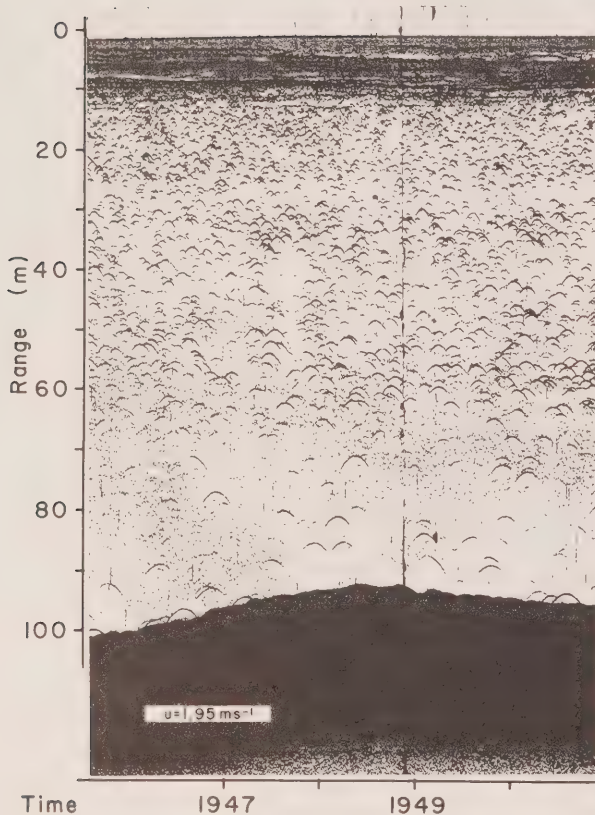


Monthly mean near-surface currents for two selected periods to show the range of observations available. The July 1980 map clearly shows the existence of the Vancouver Island Coastal Current which we believe is driven partly by flow out of the Juan de Fuca Strait and partly by local runoff producing a seaward buoyancy flux. A southward jet along the shelf edge is also visible and appears to be a typical summer feature. The December 1981 map shows some degree of consistency between all sites (except Cape St. James) at very low frequencies. A strong northward flow moves along the coast of Vancouver Island in winter becoming more intense as it does so. However, at the northern end of the entrance to Queen Charlotte Sound the current weakens and turns and we see an intense southward flow coming down the west coast of the Queen Charlottes. This produces an intense shear across the entrance to Queen Charlotte Sound.

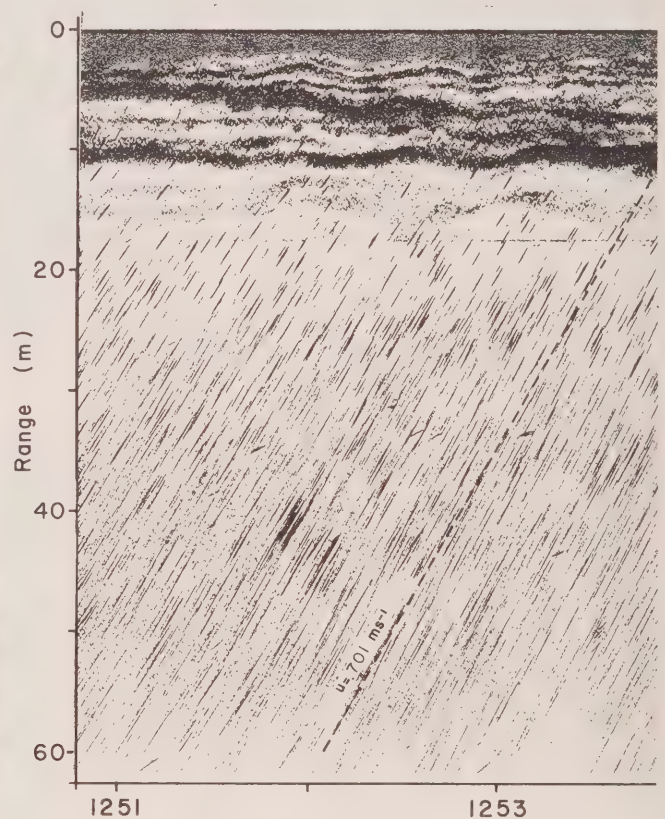
winds and the fresh water content or upper layer thickness in Alice Arm. The forcing of the circulation in Alice Arm, therefore appears to be from outside, i.e. Observatory Inlet. The deep and intermediate water exchanges are also forced from outside the fjord. Deep water renewal which occurs between January and March is coincident with strong outflow winds in Observatory and Portland Inlets. Intermediate water renewal occurs in the summer and is precipitated by the deep water renewal in Observatory Inlet. Investigations are continuing on the internal resonant response of Alice Arm to tidal forcing. (Contact: D.M. Farmer.)

Analysis of intermediate water exchanges between Alberni Inlet and the adjacent coastal sea have demonstrated their dominance over the circulation of Alberni Inlet during the winter months. These large exchanges have, in part, been explained and modelled by forcing of the fjord by wind-induced upwelling on the adjacent continental shelf. They may also be forced by fluctuations in the Vancouver Island coastal current. Renewal of the deep basin waters of Alberni Inlet occurs during the summer upwelling seasons; however, the events in these renewals have been shown to be unrelated to wind events or current features on the adjacent continental shelf. (Contact: D.J. Stucchi.)

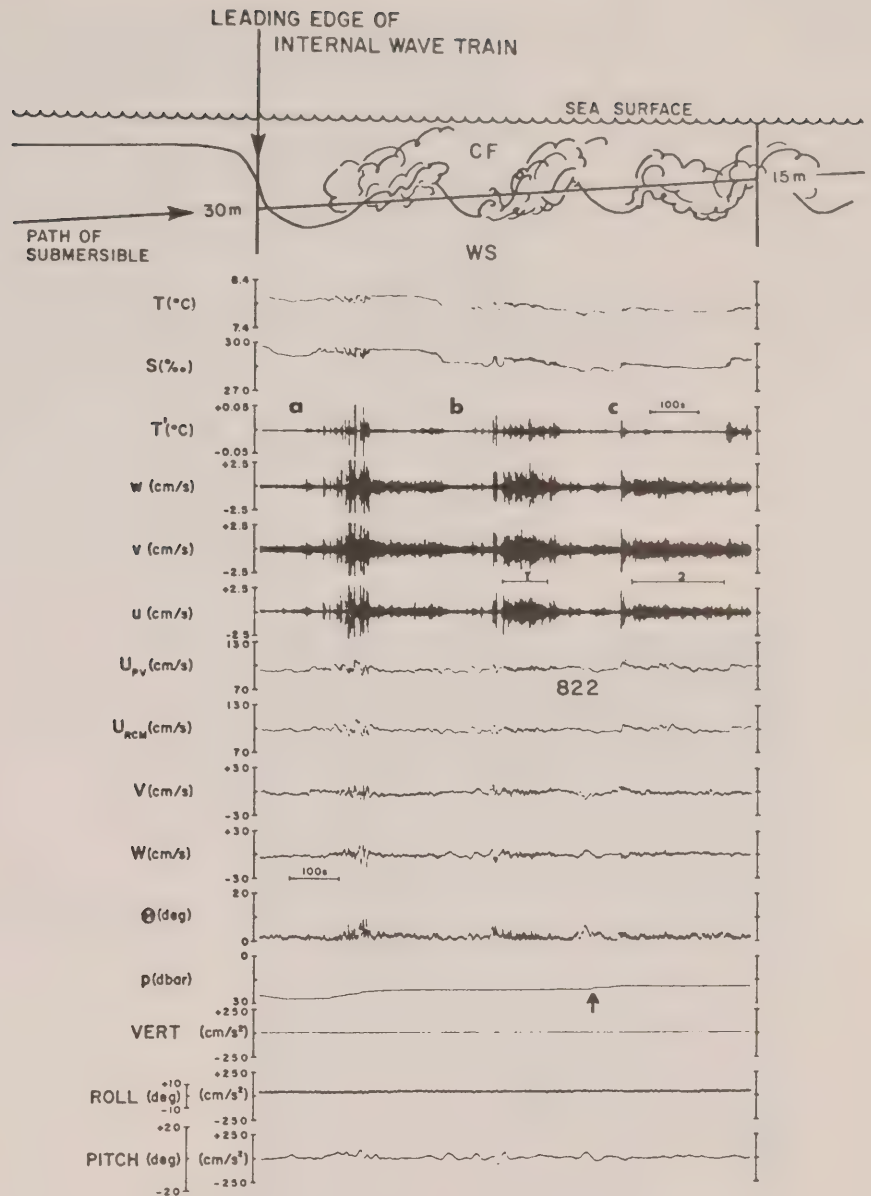
As part of a developing program in ocean acoustics, measurements were taken with sonar devices designed to explore Doppler and correlation techniques. Observations in Alice Arm demonstrated the very low levels of random motion exhibited by scatterers near the inlet head ($u' < 1.2 \text{ cm s}^{-1}$) and both Doppler and correlation techniques provided a detailed description of sill flows in the vicinity. The first tests were carried out with the echometer, a device originally designed for remote measurement of temperature profiles in the atmosphere and now being tested in the ocean. A successful test of ambient noise measurements was carried out in Queen Charlotte Sound. In addition to accurate and continuous measurement of wind speed, the listening devices also allowed the first unambiguous use of ambient noise to provide a measurement of precipitation, separable from the wind record by virtue of its unique spectral signature. The acoustics program has now been extended to include graduate students through a program with the Physics Department at the University of Victoria. (Contact: D.M. Farmer.)



(a) Curved traces made on an echo-sounder recording by small targets, probably zooplankton, as they move beneath the ship. The shape and curvature of the traces can be used to recover their speed and thus generate a profile of speed against depth.



(b) These traces are similar to those shown in (a), but are made with a narrow beam echo-sounder pointing forwards. Correlation calculations not only give the speed as a function of range (about 0.7 ms^{-1} in this image) but also allow calculation of the fluctuation velocity component.



Records of variables measured by the turbulence package on *Pisces IV*, as the submersible travelled through the leading edge (left-hand side) and subsequent waves of an internal wave train in Knight Inlet, B.C. The cartoon at the top is consistent with fields directly measured along *Pisces'* path and with high-frequency acoustic images of turbulent structures with similar wave trains. Measurements of dissipation-scale temperature (T') and orthogonal velocity components (u , v , and w) indicate the highly turbulent nature of flow in the trailing edges of waves in the train.

During 1982, much of the turbulence data obtained from the *Pisces IV* submersible operating in Knight Inlet, B.C. was analyzed. A detailed examination of the three-dimensional velocity measurements (in preparation) will clarify the degree to which turbulence in a stratified fluid achieves isotropy by dissipation scales, thus allowing estimation of turbulent kinetic energy dissipation rate from measurement of a single component of the dissipation tensor.

A prototype FLY (Fast Light Yo-yoing) profiler for measuring in the upper ocean was built, with modifications to plans supplied by Dr. N. Oakey of the Bedford Institute of Oceanography. This profiler will be used in association with the CZO acoustic Doppler system to investigate the connections between energy-containing and dissipation scales of turbulence. A semi-automated procedure for dealing with the large quantities of data expected from the FLY system was also devised and tested during the past year. (Contact: A. Gargett.)

□ □ □ □ □ Frozen Sea Research □ □ □ □ □ □ □ □

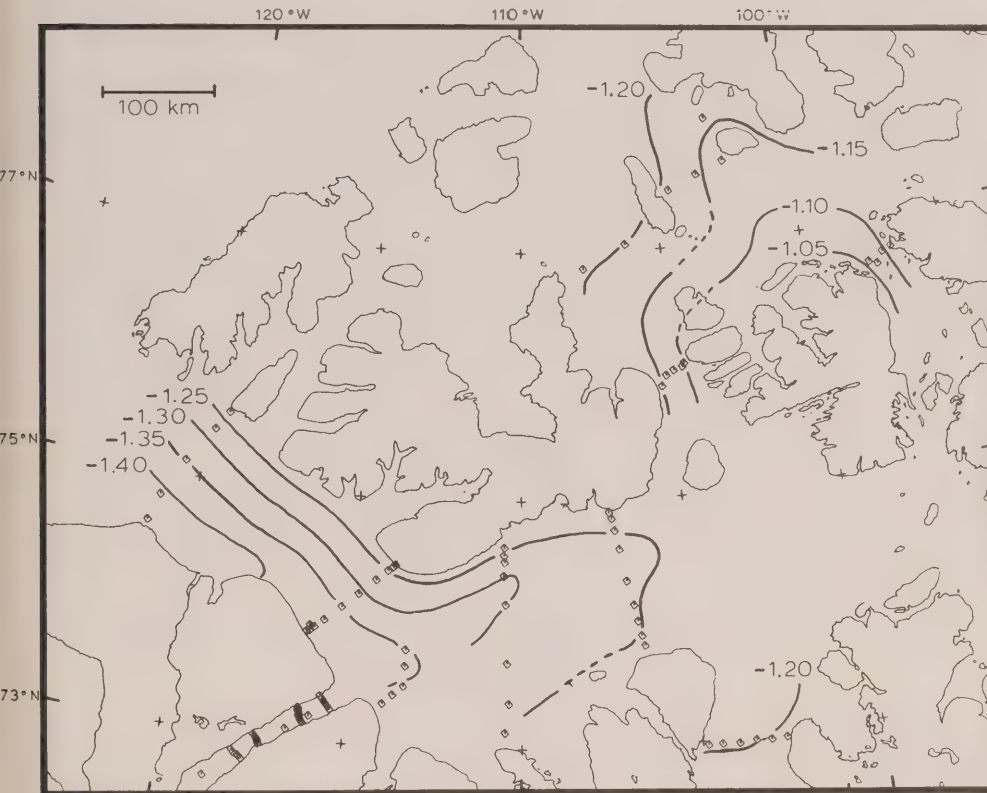
The Frozen Sea Research Group undertook three field operations during 1982: the first, in conjunction with the studies of the Northwest Passage (Transport R&D); the second, a "channel flow" experiment aimed at acquiring a year-long record of near-surface flow in an Arctic channel by a method less subject to instrument damage by ice than direct current measurement; and the third, oceanographic investigation in the vicinity of the Ross ice shelf in Antarctica, as part of a U.S. National Science Foundation project.



A current meter array being deployed in Austin Channel in the Northwest Passage will record data on the seasonal variability of flow for a twelve month period.

The Northwest Passage observations were carried out in conjunction with the Bayfield Laboratory and CHS, Central Region. IOS studies centred on the western

part of the Parry Channel; while contracted work included a CTD survey which covered most of the channels in the archipelago, with a concentration of effort in Amundsen Gulf. Observations included surface currents, water level measurements, and CTD profiles in western Viscount Melville Sound, M'Clure Strait and Prince of Wales Strait. Data analysis is underway and two long-term moorings will be recovered from M'Clure Strait in the spring of 1983. The channel flow experiment used pressure height gauges placed on both sides of Prince of Wales Strait at 20 m depth to estimate flow at that level. During the spring of 1982 a string of current meters placed across the Strait at the same depth was utilized to determine directly the width-average flow at that time and hence calibrate the differential pressures measured by the gauges. It is anticipated that a year-long record from these gauges, to be recovered in August 1983, will allow the corresponding variations in flow to the inferred. (Contact: R. Lake, H. Melling.)



Map of the western Canadian Arctic Archipelago displaying isotherms ($^{\circ}\text{C}$) for water of salinity 33.5 (approximately 150 m depth). In the Arctic Ocean waters of this salinity have temperatures less than $\sim -1.4^{\circ}\text{C}$, and form part of the cold, nearly isothermal pycnocline which is maintained by freezing processes in peripheral shelf seas. Within the Archipelago these freezing processes are no longer important, and the waters entering from the Arctic Ocean are able to warm as they move eastward because of thermal diffusion from below. Near the shallow (~ 100 m) sills restricting passage beyond the eastern edge of the map, waters almost 1°C above freezing are accessible for mixing to the surface by the energetic flows over the sills. It is this reservoir of heat which inhibits sea ice formation downstream of the sills and maintains the polynyas for which the area is well known. (Data from the 1982 Northwest Passage Oceanography Program.)

The contracted CTD survey is the most comprehensive survey to date covering the archipelago as a whole. Preliminary results show, for the first time, a systematic increase in temperatures within the pycnocline from west to east as the flow of water from the Arctic Ocean moves towards Baffin Bay. The warming appears to be a consequence of upward diffusion of heat from the Atlantic layer which is not counteracted by the draining of freezing water from the adjacent shelves as is the case in the Arctic basin. Mean surface flows are weaker than had been expected but vertical shears are significant. (*Contact: H. Melling, R. Lake.*)

Studies in Anarctica, which took place between October and December, included a complete CTD survey of the McMurdo Sound and detailed studies of the formation of anchor ice on the seabed. Surveys were conducted moving away from the Ross Ice Shelf to show the effect of this major ice face on the surrounding water masses. Data is presently being reduced. (*Contact: E.L. Lewis.*)

During 1982 the documentation of studies of a polynya in the Canadian Arctic Archipelago was completed. Three papers on the subject discussing respectively the oceanography, the atmospheric turbulent heat flux, and the total heat balance of the Dundas Island polynya during the winter/spring period, will appear in the *Journal of Geophysical Research* in 1983. (*Contact: D.R. Topham.*)

Work was also completed on the formation of gas hydrates during oil well blowouts at depth and its implication in terms of the circulation resulting therefrom. Staff also became involved with experiments to determine the possibility of subsea containment of underwater oil well blowout. Advice was requested on experiments carried out in Florida during February 1982 and on the subsequent interpretation of results. A major portion of the study on the transfer function of conductivity cells from conductivity-temperature-depth instruments was completed. This work is of particular importance to the interpretation of oceanographic data taken in the presence of fine structure in temperature and salinity. A start was made towards the planned study of ice/water/topography interactions in shallow Arctic seas while laboratory experiments were carried out to investigate dense convection currents along a sloping bottom. These small scale experiments illuminate observations made in nature on a much larger scale. (*Contact: D.R. Topham.*)

Study of data from the Beaufort Sea resulted in the publication of a paper on shelf drainage and its relationship to the Arctic Ocean pycnocline.

A preliminary study of data from the EUBEX (a joint IOS-University of Washington Eurasian Basin survey) showed that a surface heat loss from the Atlantic waters entering the Arctic Ocean through Fram Strait occurred in two locations, close to the shore of N Svalbard and about 300 km offshore. Supercooling of surface waters was frequent and appears associated with the presence of pressure ridges and the dependence of freezing point on depth. It will have a significant effect on air/sea energy exchanges at high latitudes especially in leads and cracks. (*Contact: R. Perkin, E.L. Lewis.*)

Many of the instrument developments carried out in 1982 were to aid oceanographic surveys conducted over the sea ice from helicopters. A lightweight

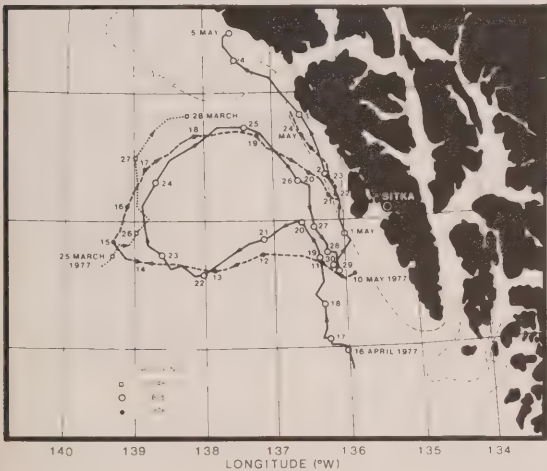
CTD winch was developed which allows observations to be made down to 500 m. Another component of the helicopter CTD system is a more compact deck unit built utilizing Guildline components having the tape recorder in the same chassis. Modifications were made to all support equipment, including range-range navigation, echo sounder, radio beacon, drilling bit assembly and power head, etc., to make them lightweight.

A major project has been the redesign of the front end of the Guideline CTD. This has been done in an attempt to improve sensor flushing and also to make the relative positioning of sensors conform to recommendations contained in the recent report of Perkin and Lewis (1982). Tests on this new design, to date successful, are continuing.

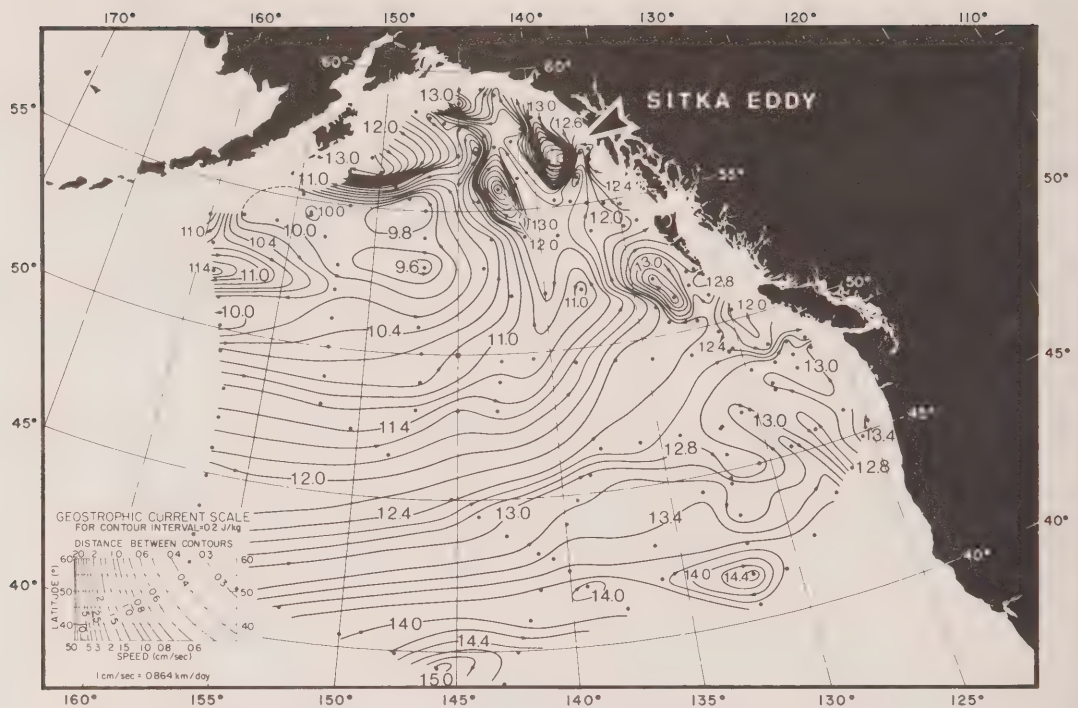
Offshore Oceanography

A total of eight cruises along Line P and two other lines, between the Canadian west coast and Station P was made during August 1981 through November 1982. These observations are made, in part, to complement the 22 years of time-series measurements along Line P and also to determine the relationship between the water properties along Line P and along the other lines. (Contact: S. Tabata.)

Oceanographic data collected in the Gulf of Alaska during 1947-1975, together with drifting buoy data, has revealed that a well-developed, anticyclonic, baroclinic eddy frequently recurs in a particular area a few hundred kilometres west of Sitka, Alaska. Atmospheric forcing and topographic interaction in combination appear to be the main generating mechanism for the eddy. (Contact: S. Tabata.)

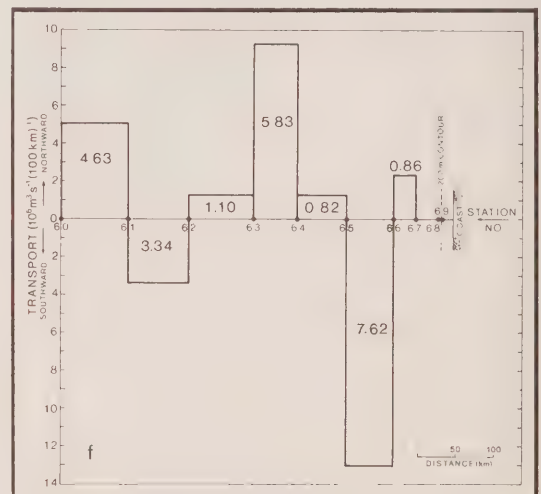


Three NORPAX satellite-tracked drifting buoys came into the vicinity of the Sitka eddy during March-May 1977. They entered the area of the eddy, each at different times—March, April and May. Yet their trajectories all appear to have described at least a part of the eddy circulation. The average surface velocity of the eddy, as estimated from the buoy drifts, was 60 cm s⁻¹.



The "Sitka" eddy is shown as it occurred in 1961. During 1954-1962 it has been observed for 6 years. A similar but lesser eddy occurred 300 km to the southwest of the main one. The contour lines are geopotential anomalies at the surface relative to the 1000-decibar surface in $J\ kg^{-1}$ (from whose gradient the surface baroclinic current velocity can be estimated).

Baroclinic transports across a section through the two anticyclonic eddies. The average baroclinic transport (relative to the 1000-decibar surface) of the Sitka eddy is 5 sverdrups ($5 \times 10^6 m^3 s^{-1}$). Maximum transport of 7.6 sverdrups occurred during 1961. The smaller eddy has only one half the transport of the main eddy.



Time series measurements of temperature and salinity profiles taken in a 40 km triangle around Ocean Station P since 1978 are being examined in order to assess the effect of advection on the time-changes of properties of water at Station P. The correlation between the advective velocity determined from the scalar field and the time-integrated atmospheric stress field is being compared with the results of time-dependent baroclinic adjustment theory. A study of the response of the upper ocean to extratropical storms in the North Pacific is being continued. (Contact: M. Miyake.)

The reduction, analysis and interpretation of data taken during the Coastal Ocean Dynamics Experiment (CODE) continued during 1982. An analysis of baroclinic and barotropic semi-diurnal tidal currents for the west coast of Vancouver Island continued, as did a comparison of observations with baroclinic and barotropic models of diurnal period continental shelf waves for the west coast of Vancouver Island. A study of the temporal variability of near-inertial current oscillations and the importance of these currents to mixing of surface waters and the low-frequency variability of currents seaward of Vancouver Island including possible existence of topographic waves and seasonally forced, baroclinic Rossby waves was undertaken. (Contact: R.E. Thomson.)

Satellite-derived sea-surface temperatures for 1980 through 1982 are being examined to delineate detailed circulation off the coast of B.C. Marked differences in the circulation were found. For example, while the January 1979 data indicated a presence of a jet of cool water directed southward, the January 1980 data showed a well-defined jet of warm water was directed northward.

In cooperation with several Australian scientists, a study of the physical oceanography of the Australian continental shelf in the area of the Great Barrier Reef was carried out for comparison with conditions on the B.C. shelf. (Contact: R.E. Thomson.)

Theoretical projects also in progress are: research on weakly interacting internal waves which seeks a theoretical description of finite amplitude interactions among internal waves and geostrophic motions and of their relation to smaller scale, stably stratified turbulence; and, an examination of the efficiency of mesoscale eddies to produce diapycnal transport, including effect of planetary wave propagation and of underlying topography. Also, a study was completed which shows that Rossby wave propagation and finite equivalent depth of a barotropic atmosphere each enhance the predictability of an atmosphere. (Contact: G. Holloway.)

A study of the use of *decision theory* in geophysical forecasting; application of functional analysis to investigate the predictability of quasigeostrophic motion; an examination of the effects of low resolution on numerical simulation of turbulence; development of inverse methods for assimilating data into numerical ocean models; and estimation of meridional heat flux in the N. Pacific Ocean based on XBT data were also advanced (Contact: A.F. Bennett.)



Numerical Modelling



In the course of joint three-dimensional model studies with the University of Hamburg, gross features of the mixed tidal regime, and of the interacting tidal residual and density driven circulation, in the bathymetrically complex, variously stratified system of straits and passages between Vancouver Island and the mainland have been reproduced. (*Contact: P.B. Crean.*)

Special interpolation of velocity vectors obtained from surface drogues (2 m depths) has permitted coherent definition of velocity fields in the shallow plume formed by the tidally modulated Fraser River discharge spreading over the denser water in Georgia Strait. The data, together with concomitant boat and helicopter STD survey, are being used in the development of a buoyant spreading upper layer tidal numerical model. (*Contact: P.B. Crean.*)

Irregular triangular grid models of Dixon Entrance, Hecate Strait and Queen Charlotte Sound for tides and storm surges are being developed. The modelling of tides in the Bay of Bengal, requested by the World Meteorological Organization was completed. A storm surge book manuscript was modified following the reviewer's comments and the final draft was submitted for publication. Some synoptic studies on explosive development of extra-tropical cyclones in the northeast part of the Pacific Ocean were completed. (*Contact: T.S. Murty.*)

An automated computer program was developed for modelling linearized shallow-water problems with an explicit finite difference method. A corresponding nonlinear version is being developed. A model of shelf and Kelvin waves was developed for comparison with observations off Vancouver Island. Analyses and tests of the phase and group velocity characteristics of various finite element numerical modelling scheme are continuing. (*Contact: R.F. Henry.*)



Remote Sensing



Following work on remote measurement of chlorophyll fluorescence at IOS, construction commenced on a fluorescence line imager, designed to provide improved data in airborne surveys of primary productivity in a joint DFO and ICS (Interdepartmental Committee on Space) enterprise. The instrument will provide improved sensitivity and spectral resolution for water colour mapping and will be used to evaluate the possibility of chlorophyll fluorescence mapping from space. The instrument will be ready for flight tests in 1983. Work at IOS continues on analysis of water colour data from existing U.S. satellite and airborne equipment. A joint Canada/German field experiment (FLUREX) provided remote and *in situ* measurements of chlorophyll fluorescence in the North Sea and Baltic Sea in April 1982, and further experiments are planned to prepare for use of the new imager in 1983. (*Contact: J.F.R. Gower.*)

An image producing system (IKONAS interactive display with OVAAC-8 and University of Miami software on a PDP-11/34) was installed at IOS in October for display and analysis of satellite data. It is already finding applications with a variety of other image data from numerical models and acoustic sounding.

Computing Services

A Data Communications Study was performed in the summer of 1982. This confirmed that data communications were significantly out of date and limiting. The existing Gandalf MiniPACX computer exchange (with a fully utilized capacity of 48 incoming circuits) was upgraded to a COMPACX IV (with an upper limit of 128 lines, and other advanced features to meet the requirement for a greater number and variety of terminal connections). Also a Univac DCP/20 front-end Communications Processor has been ordered to replace the now obsolete CTMC (retained from the old Univac 1106 configuration), which will allow higher speed computer graphics, protocol flow control to intelligent devices and non-standard device support.

In April 1982, DATAPAC access to the Univac system was expanded to four channels (via a PIN9102 depacker). System developments included a change in the batch scheduling algorithm to give higher priority to jobs with shorter estimated run times. Maintenance and updates to system libraries and processors continued, including the installation of version 2.95A of System 2000 (database management). In addition, a high level Graphics package was obtained from the National Centre for Atmospheric Research (NCAR) and implemented on the Univac and the Tektronix Interactive Graphics Library was acquired.

A Floating Point Systems AP190L array processor became fully operational in September 1982. Utilization of the AP reached a high of four users (logging 117 hours in December) with computationally-intensive numerical problems. A second remote batch terminal (in the form of a used Comterm 1000) was purchased and installed in the Computing Services wing of the IOS main building complex providing much better access for remote job entry and output to the several groups located nearby.

An assessment of the user workload showed an apparent increase of 9% in 81/82 over the previous year. However, accounting for a unit price reduction of 30% in processing charges and 80% in file storage charges, the actual workload increase was a factor of 2, reflecting the greater processing power and storage capacity of the new system.

In September a new resource control system for Univac users was implemented. The total cost, including rate factor and connect-time charges, is displayed at the end of a run and charged immediately against the user's allocation.

To facilitate the procurement process for an increasing number of system analysis, programming, and data processing contracts, Standing Offers for EDP Professional Services totalling over \$300,000 were established with three firms.

Developments of data base applications using the System 2000 DBMS on the Univac system was accelerated. For the Library Book Catalogue, reporting programs to print the various catalogues were enhanced and completed; output is now to magnetic tape from which microfiche is prepared by an external service. The database input program was modified to be tabledriven; this has facilitated the implementation of several new applications. These include bibliographies and inventories of oceanographic data, primarily for the Pacific coast and western Arctic (Beaufort Sea) regions, for the Ocean Information Division. Management Services converted to System 2000 for two record keeping applications. Other new users included Frozen Sea Research Group, Ocean Ecology and Personnel Divisions. (Contact: K. Teng.)



Central computing facility at IOS; showing the Univac 1100/60.

Ocean Chemistry



The major objective of the Ocean Chemistry Division is to provide expertise, advice and a scientific perspective on both short-term and long-term problems associated with the chemical aspect of the ocean environment through both monitoring and research activities. Five areas are of prime concern: ocean pollution, ocean climate, ocean fluxes, ocean circulation and ocean productivity. The major effort is directed towards basic scientific understanding of the long-term consequence of anthropogenic manipulation of the natural environment, but a balance is also struck by studying the short-term environmental impacts of societal intrusion.



A benthos gravity corer being deployed in Observatory Inlet for the dating of sediments.

Amax

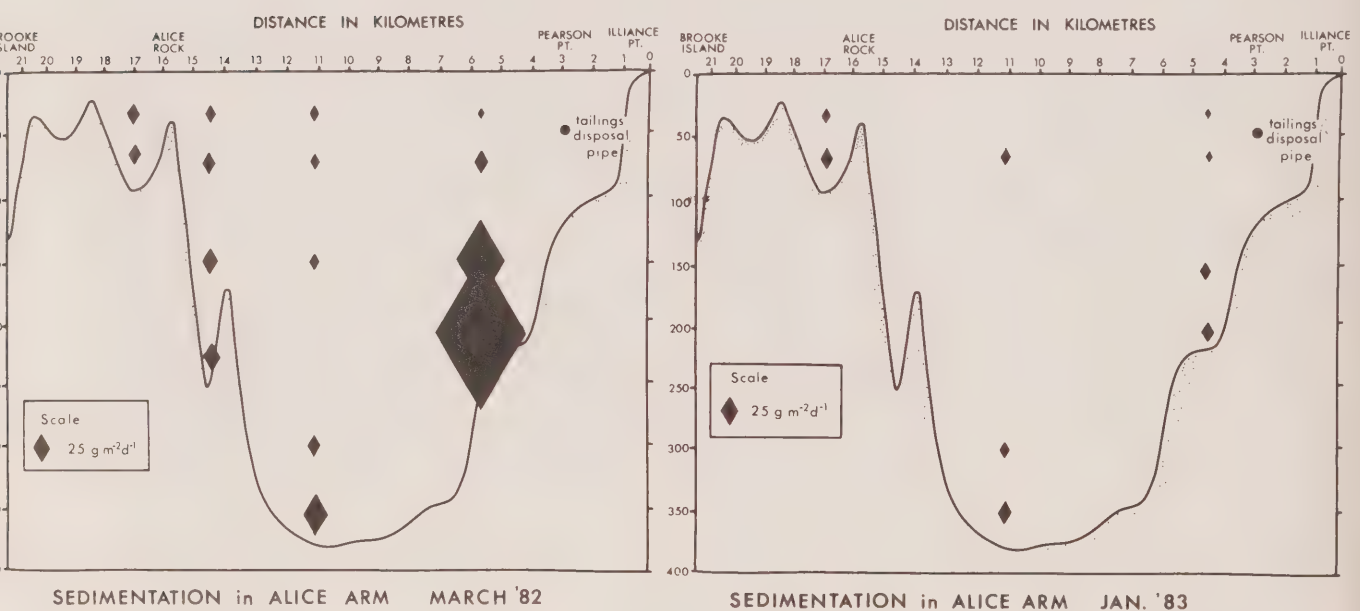
In response to a requirement for baseline levels and processes affecting the distribution of tailings disposed into Alice Arm, as pointed out by the Amax Mine Review Panel, a crash program was launched to provide new knowledge through research and monitoring studies.

The chemical program consists of four components: the determination of trace metal levels in the sea water column of Alice Arm and in inlets in the vicinity, a study of metal build-up in pore waters of bottom sediments polluted by mine tailings, a laboratory study of the metals released from tailings suspended in sea water and the establishment of sedimentation rates of mine tailings and metal content of particulates collected by sediment traps.

Cruises were conducted in the Alice Arm area to obtain seasonal pictures of chemical oceanographic variabilities, to determine fluctuations in natural inputs of metals in particulates and in mine tailings inputs, to launch and retrieve sediment traps, and to sample pore waters and sediments.

Sediment and pore water studies are in progress with the analysis of core profiles of sediments for a suite of metals (Cu, Zn, Pb, Cd, Mo and Mn) to establish levels for pre- and post-start up of the Amax mine and to assess the metal build-up in pore waters. Preliminary data on the radioactivity of Uranium-238, Thorium-232 and Potassium-40 from Ocean Chemistry Division and from the Pacific Geoscience Centre indicated no elevated concentrations of these nuclides associated with past tailings deposits or current tailings. (Contact: J.A.J. Thompson.)

Data from moored strings of sediment traps have led to the conclusion that mine tailings disposed of by the present method seem to settle close to the outfall and that tailings have moved a further distance as a bottom nepheloid layer rather than as a water column plume. Samples from a trapline set within one kilometre of the outfall contained mainly tailings material at 150 m and at 200 m depth, but only 50



percent as tailings material at 70 m depth. No obvious tailings were found in sediment traps set within 10 km of the Amax outfall. (Contact: R.W. Macdonald.)

Preliminary data of trace metals in sea water columns indicated that from the pre-dumping period, sea water samples in the Nass River estuary had higher values of total cadmium, lead and zinc than did samples taken in Alice Arm. During a high runoff period in October 1980, there was substantial mobilization of total metals in Alice Arm with a factor of 5 higher in cadmium and zinc and of 10 in lead, compared to the Nass River estuary. A new technique, using lead-206 and lead-207 isotopic ratio to trace the extent of mine tailings contamination in Alice Arm, was developed successfully through an unsolicited proposal by Seakem Oceanography Ltd. The IOS clean laboratory and mass spectrometer were used. (Wong, Stukas.) Dissolved copper in Hastings Arm showed a high subsurface peak at about 70 m compared to generally low values in Alice Arm, thus indicating possible leaching input from an old mine heap at Anyox. (Contact: C.S. Wong.)

Marine Carbon Research Centre

The Ocean Science and Surveys Marine Carbon Research Centre at IOS, now in its fourth year, is focussing on the marine aspects of the global carbon dioxide (CO₂) cycle by conducting research, monitoring and modelling activities. An emergent consensus of the scientific community which warns of a possible 2-3°C warming due to future CO₂ doubling in the atmosphere with a possible increase of 0.1-0.5°C per decade, has led to an urgent need to understand the mechanism of the global CO₂ cycle. In particular, it is important to study the ocean's capacity to absorb atmospheric CO₂.

CO₂ monitoring is an essential tool in recognizing the first signals of oceanic CO₂ increase and in establishing the secular increase and long-term variability. The ocean CO₂ monitoring program has been using three types of platforms: ships-of-opportunity, research cruises along Line P, and B.C. lighthouses. The ships-of-opportunity program using the *Canada Ace* between Tokyo and Richmond, B.C. and the *Lillooet* between Sydney, Australia; Noumea, New Caledonia; and Tacoma, Washington continued to provide the CO₂ time series and oceanographic properties of the Pacific Ocean for research and modelling. The Carbon Research Centre also assumed a lead role in organizing an international working group of the Scientific Committee on Oceanic Research (SCOR) on ocean CO₂ monitoring to map out a global strategy and to review various national capabilities for international cooperation. (Contact: C.S. Wong.)

CO₂ research in 1982 was highlighted by participation in the *Discoverer* cruise of the Pacific Marine Environmental Laboratory (PMEL) of the U.S. National Oceanic and Atmospheric Administration (NOAA) in western and equatorial Pacific waters. In cooperation with PMEL, air-sea partial pressure of CO₂ was measured using a new gas chromatographic technique. An intercalibration of this IOS total CO₂ method with the PMEL titrator approach was also made during the cruise. CO₂ modelling was initiated with the support of a new postdoctoral research fellow with

activities concentrating on a diagnostic model of Canadian atmospheric CO₂ to establish sources and sinks from the Canadian land forest, and Arctic and ocean reservoirs. CO₂ regeneration processes to convert organic carbon into CO₂ in the marine environment were also initiated with the assistance of a postdoctoral research fellow. (Contact: C.S. Wong.)



A deep-ocean sediment trap being deployed at Station P in co-operation with staff from Wood's Hole Oceanographic Institution.

Hydrocarbons and Pesticides

The objective of the program is to advance the knowledge of the occurrence, pathways and fate of hydrocarbons (natural, petroleum-based, chlorinated and pesticides) in the marine environment.

Histological and chemical survey of bivalves was conducted under contract at the Alberni Inlet dump site and in local southern Vancouver Island waters. At the first location, histopathological examination of bivalves and other organisms did not show signs of environmental stresses. In contrast, evidence of stresses was uncovered in southern Vancouver Island waters with mussels from Cowichan Bay showing the poorest histological condition; those from McLaughlin Point, intermediate condition; and those from Hatch Point, the best. Hydrocarbons of intermediate volatility (10-20 carbons in the chain compound) were found to be lowest in mussels from Hatch Point. Evidence of proliferative disorders in mussels in the southern Vancouver Island study area were found with hemopoietic neoplastic disorders being prevalent. A first identification of a gonadal neoplasm disorder was made in *Mytilus edulis*. In contrast to the southern Vancouver Island waters bivalve study, similar studies in the Alberni Inlet and Kitimat areas have failed to find evidence of proliferative disorders.

Instrument development included work on a fibre-optic photoacoustic detector which is being developed in cooperation with the University of Victoria for *in situ* measurement of oil dispersed in sea water. A hermetically-sealed sediment drier which removes water by molecular sieve without losing volatile compounds was designed and built at the Institute for use at room temperature. (Contact: W.J. Cretney.)

Ocean Flux

Ocean flux experiments were carried out under two international cooperative programs: SEAFLUXES and PARFLUX. Two SEAFLUXES enclosed experiments were performed. The first was a spring bloom experiment, performed with the participation of Dr. B. Imber of Royal Roads Military College relating to chelation of zinc and with Dr. F. Pollehne of the Institut für Meereskunde at Kiel, F.R. Germany, working on the change of C/N ratio and pigment composition of phytoplankton approaching nutrient or light limitation. The second was a mercury experiment in which two bags were launched in June to study the pathways and fate of mercury in sea water and the effect of biological forcing of phytoplankton growth on mercury distribution. This experiment was carried out in cooperation with Mr. X. Lu of the Shandong College of Oceanology and Mr. J. Wu of the Third Institute of Oceanography at the Chinese Bureau of Oceanography. In August, a working group meeting with representatives from the National Bureau of Oceanography in China, the International Development Research Centre in Ottawa, U.B.C., and officials from both Ocean Science and Surveys in Ottawa and in the Pacific Region was held to define the scope of future Canada/China cooperation in the study of marine pollution dynamics using such an ocean enclosed experiment technique. (Contact: C.S. Wong.)

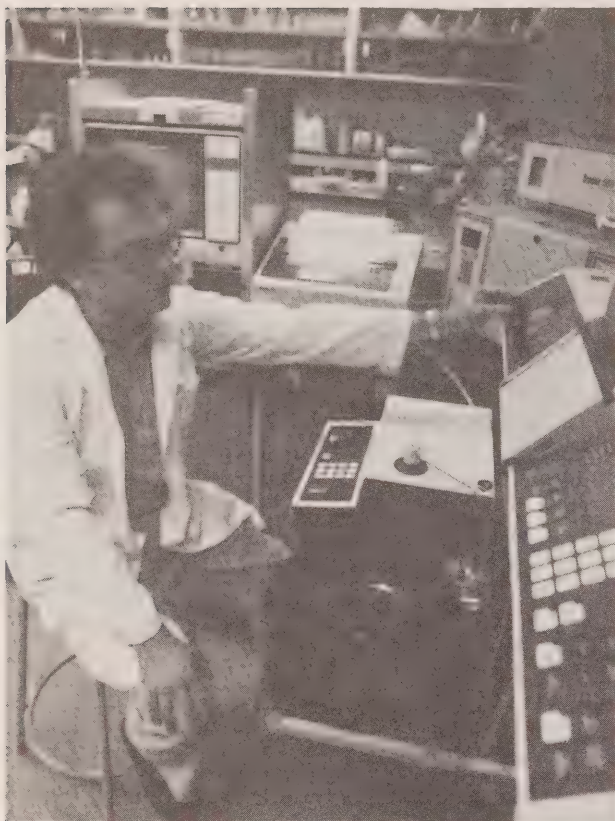
Under the PARFLUX program, a cooperative venture with Woods Hole Oceanographic Institution (Dr. S. Honjo) was initiated in 1982 with the mooring of an automated sequential sediment trap at Ocean Station P (50°N 145°W) in October to study fluxes of metals, hydrocarbons, carbon cycle, and mineralogy/morphology of particles in the open ocean. (Contact: C.S. Wong.)

Fjord and Arctic Chemistry

The objective of the program is to gain new knowledge of the environmental factors controlling the circulation and sedimentation in B.C. fjords and in the western Arctic. Such new knowledge will contribute to environmental impact statements and assessment of pollutant effects associated with development of the western Arctic for oil and gas, and with increasing industrial activities in coastal inlets of B.C.

Field activities were devoted mainly to the Alice Arm fjord system as described above. Other activities included the publishing, as workshop proceedings, of previous Kitimat fjord studies, including those by other agencies and IOS divisions covering physics, chemistry, geology, biology and hydrography. The Division also provided scientific authority on Arctic data compilation contracts and coastal data

information contracts. Because of increased drilling activity, Ocean Chemistry scientists were heavily involved in the Beaufort Sea oil production Environmental Impact Statement, in the Risk Analysis of sea and land transportation routes and the disposal of offshore drilling fluids. (Contact: R.W. Macdonald.)



Research scientist conducting metal determination of sediments by atomic absorption spectrophotometry.

Coastal Pollution

The objective of the program is to understand the detoxification mechanism of metal-protein complexes (metallothioneins) in marine organisms and their transformation mechanisms and organometallic species in the marine environment so that environmental significance of "pollutants" can be assessed in a meaningful way.

For the metallothionein work, the polarographic technique was further developed with a detailed study of the temperature-dependence of polarographic response. Field study, in addition to that discussed under Amax, includes a cooperative project with the Royal Roads Military College (Dr. K. Reimer) on arsenic speciations in Rupert Inlet involving the collection of a series of sea water and sediment samples for chemical speciation analysis. Another cooperative project with DFO's Freshwater Institute in Winnipeg (Dr. B. Fallis) consisted of an exercise

to evaluate the analysis of clam tissues for lead and other metals associated with the Nanisivik mine monitoring program. Ocean Chemistry Division also provided freeze-dried clam tissue from local sources to a number of Canadian government and commercial laboratories for inter-calibration.

During 1982 there was much demand for Coastal Pollution staff to provide advice and expertise concerning such activities as ocean dumping, the examination of organotin compounds under the National Research Council, the environmental monitoring of the Nanisivik Mine and Amax review panel deliberations. Discussions were also held with various industrial and consulting firms. (*Contact: J.A.J. Thompson.*)

Trace Metals

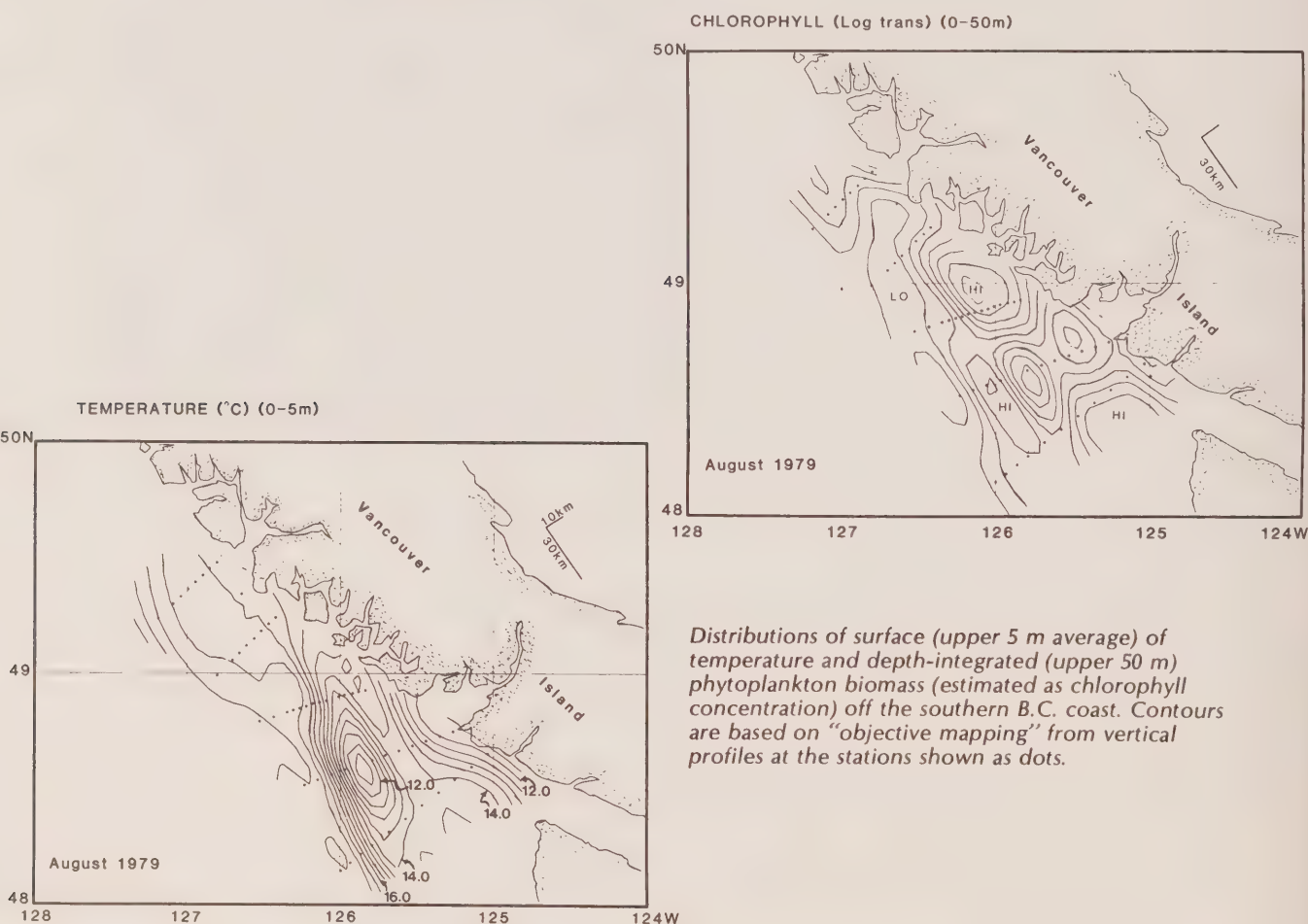
The objective of the trace metals program is to assess the distribution and fluxes of natural and man-mobilized metals in the ocean, especially their interaction with suspended matter, the planktonic biota and surface sediments.

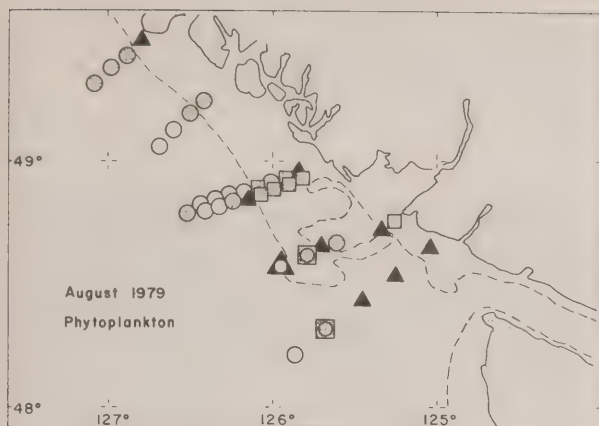
The study priority has shifted from open-ocean to coastal waters to accommodate the Amax program and the demand for knowledge required for ocean dumping decisions. To understand the seasonal cycling of mercury, a time series on mercury distribution in Saanich Inlet was obtained using sediment traps at monthly intervals. Total and particulate mercury, organic mercury, temperature, salinity, POC, oxygen, sulphide and mercury fluxes were recorded. The work was performed as a cooperative effort with a visiting scientist from China, Mr. X. Lu. During the study period, mercury of around $1 \mu\text{g L}^{-1}$ total mercury in sea water, lower than any reported value, was observed in the surface waters. A significant build-up of organic mercury was observed in the bottom waters and pore waters of sediment of the Inlet during the sulphide build-up in the summer. Sea water for mercury standard was also collected for certification study both at IOS and at the Jülich Nuclear Research Institute in F.R. Germany. This study is being conducted in cooperation with Dr. Nürnberg on behalf of the IUPAC (International Union of Pure and Applied Chemistry) natural waters program. A long-term storage study of mercury in sea water and a short-term release rate study of mercury from sediment were also conducted. (*Contact: C.S. Wong.*)

An ocean dumping release experiment was conducted for lead and cadmium using sediments from the False Creek area in Vancouver which are known to be contaminated by high cadmium and lead. The experiment was carried out in the clean room and the metal values were determined by ultra-clean room manipulation and mass spectrometry. The release/absorption characteristics were different at low, medium and high concentrations of metals. For example, cadmium at 1 ppm concentration of solid in sea water was at equilibrium while at 100 ppm level showed a rapid uptake of almost all the cadmium in solution followed by a rapid release after two days. Lead, on the other hand, showed steady increase in concentration over time. Further study is being pursued with high mercury sediment. (*Contact: C.S. Wong.*)

Plankton

Analysis of data from a four-year field program off the southwest coast of Vancouver Island revealed a planktonic ecosystem that is highly productive throughout the spring and summer. The nutrients that fuel this production flow up the Juan de Fuca submarine canyon system to the surface waters at the centre of the continental shelf from deeper offshore waters. This upward flow is caused by a counter-clockwise circulation above the canyons. Mathematical and statistical techniques were developed which allow the integration and comparison of physical data, continuous measurements of biomass, and discrete counts of species abundance levels by analysis of the spatial patterns. (Contact: K. Denman, D. Mackas.)





Community composition of phytoplankton and zooplankton for the same time period shown in preceding figures. Symbols indicate station groups identified as having similar species dominance hierarchy by multivariate cluster analysis.

Similar techniques were used to study the small-scale zooplankton community pattern in the Alice Arm/Observatory Inlet system. Results to date suggest a differing compositional hierarchy near the head of Alice Arm. The difference is small, however, compared to the range of temporal variation. Laboratory studies using video monitoring equipment were undertaken to measure activity levels of zooplankton close by and away from the Amax mine outfall in Alice Arm. Findings will be published in 1983. (Contact: D. Mackas.)

Work on fine-scale (less than one kilometre) zooplankton pattern continued in Georgia Strait near the freshwater plume of the Fraser River. Papers were published on the signal resolution of flow-through pumping systems and on the potential impact of new plankton sampling developments on fish larval ecology. (Contact: D. Mackas.)

Studies of the influence of physical processes on the planktonic production continued. A theoretical study on the effects of vertical movement and light variation on primary productivity was completed. Another, on the numerical simulation of horizontal turbulence and phytoplankton patchiness, was initiated. New methods and equipment were developed to study the effects of variable light fields on phytoplankton productivity. One such system is a computer-controlled turbidostat which keeps the turbidity in the culture vessel at a constant level and thus maintains a constant phytoplankton concentration. (Contact: K. Denman, S. Hill, R. Forbes.)

Since the plankton sampling program using ships-of-opportunity was disrupted due to a prolonged tie-up as a result of the economic recession, IOS research cruises were used, on an as-available basis. This allowed a more varied spatial coverage but at the expense of repeated sampling along the same line. (Contact: D. Mackas.)

A copepod manual for B.C. waters was completed under contract and has been reviewed. The work will appear as a Fisheries and Aquatic Sciences Special Publication.

Benthos

The initial results are encouraging from the almost complete continental shelf benthos project which is being done under contract. Identifications of the major phyla and the dominant species from other phyla have been completed, and biomass estimates are now being made. Initial statistical analyses show that computer programs are functioning well.

Work on aquatic oligochaetes in 1982 included publication of a theoretical study of evolution in annelids. This material was also presented to the Second International Symposium in Pallanza, Italy. Progress was made on an update of a world taxonomic monograph produced a decade ago, and on descriptions or revisions of various taxa. In 1982 there was also considerable time spent in the provision of advice to consulting and industrial concerns around the world. Field and laboratory work on the squat lobster *Munida* in Saanich Inlet demonstrated good correlation. The largest animals have the lowest respiration rate and the largest gill mass and are found closest to the anoxic zone in the field. These animals migrate up and down the fjord walls just ahead of shifts in the level of deoxygenated water. In fjords without an anoxic zone, the animals are present at all depths and there is no size or gill mass difference in populations from various depths. (Contact: R.O. Brinkhurst, H.R. Baker, K. Coates, B. Burd.)



Corals and anemone. Cobb Seamount (375 m depth).



*King crab on an inactive hydrothermal vent site.
Brown Bear Seamount (700 m depth).*



*Rockfish in a sea of brittle-stars.
Brown Bear Seamount (490 m depth).*

A long-term monitoring project to establish the effect of mine tailings on sea-bed life was initiated. Samples were taken from the main basins of Alice Arm and Hastings Arm, well beyond the effluent outfall, and are now being analyzed.

The deep-water benthic program was expanded in 1982 with continued *in situ* investigations of rocky-bottom communities using the submersible, *Pisces IV*. During two autumn cruises, the faunas of several fjords were examined. An unusual assemblage of brachiopods and black coral was discovered in the Queen Charlotte Sound fjords, as well as numerous new species and new records of invertebrates. Collaborators include: Drs. W. Austin (Khoyatan Marine Laboratory), G. Mackie (University of Victoria), B. Gulliksen (University of Tromsø, Norway), and H. Reiswig (McGill University).

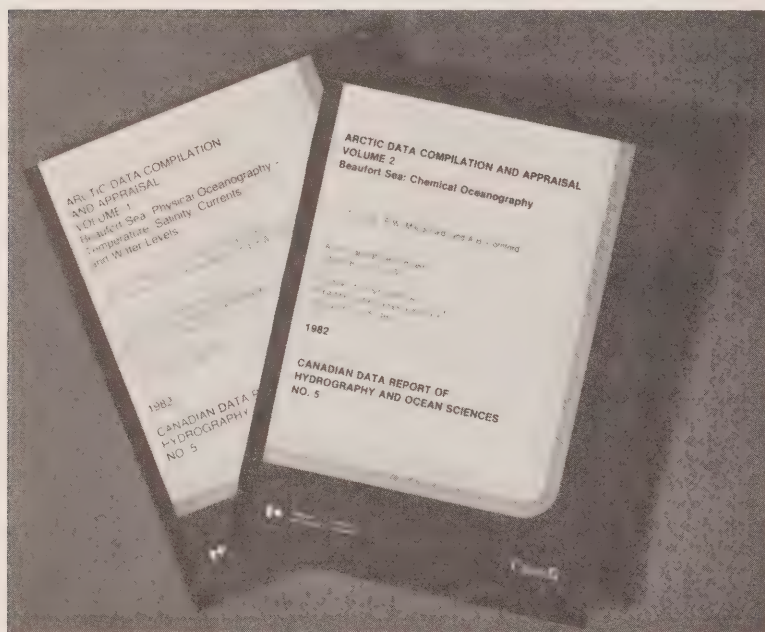
During August and September, two cruises to Cobb and Brown Bear Seamounts, 500 km offshore, were conducted to detail shallow-water animal assemblages and their relationships to young, volcanic substrata. Biologists and geologists from the University of Glasgow, University of British Columbia and University of Washington combined their efforts to study this area of continuing geological activity. The discovery of hydrothermal vents at this site will stimulate future investigations.

□ □ □ □ □ Ocean Information □ □ □ □ □ □ □ □ □

Ocean Information Division activities support the management and exploitation of marine resources. Primary responsibilities include the collection and dissemination of oceanographic research data, the conduct of marine climatological analyses, the evaluation of environmental reviews, and the provision of information and advice through various committees to regulatory agencies. The Division also oversees the regional ocean dumping research program, provides information to the public, media relations, and policy and planning support for regional operations.

Oceanographic Data and Climatological Services

During 1982 a joint government/industry program to catalogue physical, chemical and biological oceanographic data sets was continued. Appraisal of data set quality has been a major component of the project to establish both the usefulness of the data and the priorities for archiving.



Hard copy volumes of Arctic Data Compilation and Appraisal; access is also available through IOS computer.

Arctic data set compilation and appraisal focussed on the Beaufort Sea and N.W. Passage — critical areas for offshore hydrocarbon development and transportation respectively, and the subject of an intensive Environmental Impact Statement (EIS) prepared by the oil and gas industry. The first volume, dealing with physical oceanographic data sets for the Beaufort Sea, was published in November 1982, and

will be followed shortly by similar volumes for the N.W. Passage, Queen Elizabeth Islands and Baffin Bay/Ellesmere Island. Data-set catalogues covering chemical oceanography for the Beaufort Sea and N.W. Passage and benthos, plankton, fish and whale inventories for the Beaufort Sea have also progressed well and will be published in 1983. (*Contact: A. Cornford, B. Smiley.*)

The cataloguing of chemical oceanographic data sets — a companion study to physical oceanographic data sets completed at IOS in 1980 covering Queen Charlotte Sound/Hecate Strait/Dixon Entrance — is well underway, as is compilation and review of west coast marine environmental assessment and data reports. (*Contact: A. Cornford, L. Giovando.*)

A project to assist with marine aspects of the west coast Coastal Zone Folio mapping program has been initiated with DOE's Lands Directorate.

The B.C. Shorestation Oceanographic Program (lighthouse monitoring program) continued to supply surface seawater temperature and salinity data from 19 locations. In 1981, marked positive anomalies in surface temperatures occurred at shorestations exposed to the open Pacific Ocean (e.g. Langara Island and Amphitrite Point). The geographical drift of the peak of the anomaly suggested a northward-propagating event moving up the outer B.C. coast at about 7 km/day. However, preliminary examination of the 1982 data indicates that in the past year no such event occurred and suggests that, in general, coastal surface-water conditions were closer to those of the more "normal" year 1980. (*Contact: L. Giovando.*)

Initial steps were taken to assess a U.S. experimental fisheries-aid program for possible Canadian application. The joint Jet Propulsion Lab — NOAA (NWS) program was designed to provide reliable environmental information for fishermen, with the help of satellite observations. Specialized techniques to improve the analysis and forecasts of ocean-surface features (i.e. winds, waves, sea-surface temperatures, and colour boundaries) may be advantageous to commercial fishing operations. (*Contact: A. Cornford.*)

Environmental Services

Assessment of historical data sets especially those concerning chemical mass balances and budgets, mobility of wastes, and physical forcing affecting ice movement and oil spills was undertaken to prepare for government review of the oil and gas industry EIS for development in the Beaufort Sea and Mackenzie Delta. Considerable IOS effort was directed to appraising the adequacy of industry's environmental assessment for Arctic offshore hydrocarbon development. (*Contact: B. Smiley.*)

Environmental review activities continued in 1982 with participation in several phases of EARP (Environmental Assessment and Review Process) and various standing committees: RODAC (West Coast and Arctic Regional Ocean Dumping Advisory Committees), AWAC (Arctic Waters Advisory Committee), ARCOD and WESTCOD (Arctic and West Coast Offshore Development Committees). Items examined in 1982 included proposals for an LNG terminal in the Prince Rupert area,

an Initial Environmental Evaluation (IEE) by Petro Canada regarding Dixon Entrance/Hecate Strait, a proposal by Gulf for an Arctic shore base at Stokes Point and an environmental review of offshore oil and gas leases for COGLA (Canadian Oil and Gas Lands Administration). (Contact: B. Smiley, L. Giovando.)

Ocean Dumping

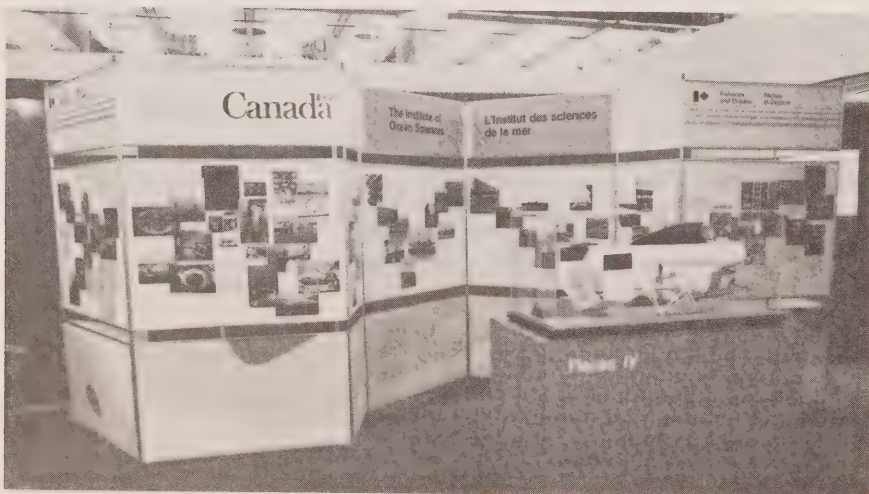
IOS maintains responsibility for the administration of the Ocean Dumping Control Act research fund for both Pacific waters and the western Arctic. Research results are available in the proceedings of the annual workshop. The Institute also serves in an advisory capacity regarding marine dredging and dumping permits issued by DOE's Environmental Protection Service (EPS). (Contact: L. Giovando.)

Information and Media Relations

IOS media relations and information activities increased with the arrival of a full-time information officer. Initial efforts involved the production of the Institute's annual review of activities, participation in the B.C. Science Fair and trade shows, and the preparation of material for publications concerning marine science, Arctic activities, and hydrography. (Contact: K. Glover.)

Policy/Program Analysis

A well-documented Program Review and Evaluation (PRE) of research and survey activities was completed by senior staff, as was an updated Multiyear Operational Plan (MYOP). Several major program analyses were also undertaken. For example, reviews of ship utilization, Arctic oil and gas programs, and other energy-related programs were completed in conjunction with contributions to departmental Main Estimates and the Improvement of Management Practices (IMPAC) exercises. (Contact: A. Cornford.)



IOS display at B.C. Discovery Fair



Ships



CSS Vector



Barge Pender

The Pacific Region Ship Division provided ship, submersible, launch and depot support for the 1982 scientific programs of the Institute of Ocean Sciences, universities and other federal agencies.

CSS *PARIZEAU* (64.3 m overall; 1929 tonnes)

Master (Acting): B.L. Newton Chief Engineer: P. Pereira

CSS *Parizeau* was employed in support of scientific programs involving Field Hydrography, Tides and Currents, Ocean Chemistry, Ocean Ecology and Ocean Physics. The *Parizeau* also provided support for Pacific Geoscience Centre (PGC) and the Department of National Defence's Ocean Acoustics section. As well, *Parizeau* participated as a primary Search and Rescue (SAR) vessel for the herring roe fishing season.

During the winter *Parizeau* has been undergoing her mid-life refit and will be out of service for approximately three months. Major replacements include main engines, generators and ancillary equipment. Considerable changes are being made to the accommodation and structure. The ship's electronic capabilities are also being extensively updated.

CSS *VECTOR* (39.6 m; 505 tonnes)

Master: K. Sjöholm Chief Engineer: R. Pearson

CSS *Vector* carried out duties in support of Institute programs in Ocean Ecology, Coastal Zone Oceanography and Ocean Chemistry. Other agencies assisted included the University of British Columbia, Pacific Geoscience Centre, Simon Fraser University and the Environmental Protection Service (EPS).

CSS *RICHARDSON* (19.8 m; 78 tonnes)

Master: R.W. MacKenzie

The *Richardson* was used mainly by the Hydrographic Division in the field surveys in the Queen Charlotte Islands and northern Vancouver Island after an initial period with Search and Rescue.

M.V. *PANDORA II*, on charter (58.2 m; 1220 tonnes)

Master: R.A. Jones Chief Engineer: W. Weston

The *Pandora II* carried out Institute programs with Ocean Ecology and provided support for the University of Victoria, DND, B.C. Provincial Museum, Simon Fraser University, EPS and the Pacific Geoscience Centre. Many of these programs were in conjunction with the submersible *PISCES IV*.

PISCES IV (6.1 m; 12 tonnes)
Chief Pilot: F. Chambers

Pisces IV, having completed her first ten years of operations and recorded 1096 dives, entered into her mid-life refit. This was divided into two periods. Phase I took place between January 3 and July 4, 1982. During this period the *Pisces IV* was completely dismantled, repaired, modified, re-assembled and recertified to 700 metres. The major portion of Phase I work was carried out by *Pisces IV* staff with engineering support provided by Witney-MacInnis Engineering Ltd. The remaining work was contracted out to private industry. Phase II of the refit, scheduled for mid-January to mid-February 1983, will see the *Pisces IV* certified to 2000 metres.

Since the completion of Phase I, the *Pisces IV* in conjunction with the mothership *Pandora II*, has completed over 110 operational dives in support of Ocean Ecology programs and those of B.C. Provincial Museum, DND, University of Victoria, Pacific Biological Research Station and Pacific Geoscience Centre.

Barge *PENDER*

The barge *Pender* was used extensively by the Hydrography Division as a base for the field survey party that operated in the Seymour Inlet and Quatsino Sound areas from May 3 to October 8, 1982. The barge provided accommodation, support and maintenance facilities. On her return to Pat Bay the *Pender* was used locally by Coastal Zone Oceanography and Engineering Services.

Institute Workshops

In addition to the normal maintenance of the Institute's fleet of over 30 launches and tenders, the workshop undertook major rebuilds of four gas, four diesel and eight outboard motors of various sizes.

The launch *Nucleus* was completely gutted, and rebuilt and re-engined as a workboat at the beginning of the year and spent a successful season in support of the barge *Pender*.

The new twenty-nine (29) foot aluminum survey launches acquired this year, the *Wind* and the *Wave*, were fitted out, field tested and painted. Two more launches of this type are to be purchased shortly.

The shops were also heavily involved in special fabrication projects for various Institute divisions and lent support to the *Parizeau*, *Vector*, *Richardson* and barge *Pender*.

Deck Machinery

Deck Machinery continued to supply equipment and services for the scientific programs of the Institute, the Bedford Institute of Oceanography, Department of National Defence as well as to non-government users. All deck machinery from the *CSS Parizeau* is to be extensively overhauled during her mid-life refit.

Management Services

Management Services continued in 1982 to provide the core support services for running the region and the Institute. These include: purchasing and materiel management, financial management, records management, communications, library services, and the operation and maintenance of buildings and grounds.

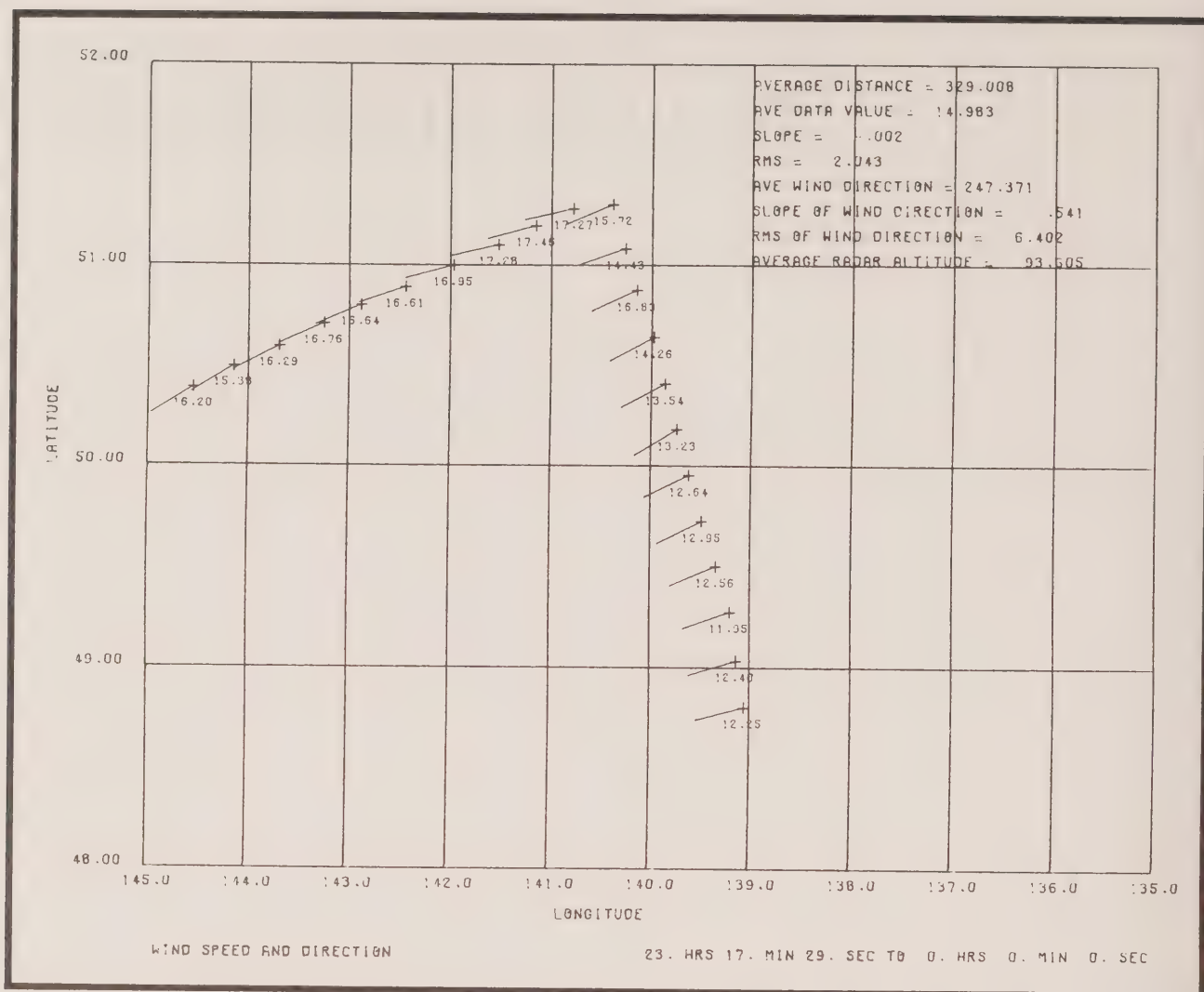
Some of the noteworthy events in 1982 included the enhancement of word processing capabilities. The region now has five stand-alone systems. These were installed after completion of an extensive study of regional needs. The telephone and other communication systems were rationalized to provide more cost-effective service.

Continued emphasis was placed on the federal government's energy conservation program. Two vehicles are now fueled by propane and two more are on order. Contracts were awarded for double glazing the main building using a new add-a-pane system. Fuel savings will recover installation costs in about six years. Studies were also carried out to improve the energy performance of the 40-year-old hangar. It is expected that the improvements will be made in 1983. The job of reroofing the hangar, including the addition of insulation, was started.

Library services operated at a satisfactory level. Development of systems and techniques using improved communication and computerized data bases continued, particularly on the departmental WAVES system.

A joint regional Ocean Sciences-Fisheries Management working group was formed to study and design improved purchasing, financial and distribution accounting systems using state-of-the-art technology for increasing productivity, processing time and for providing better control.

DEPARTMENT OF THE ENVIRONMENT



Measurements of wind from aircraft, using sensitive inertial navigation systems, can be used to provide detailed information on wind variability over the ocean. The lines indicate wind direction; the numbers give the speed in m/s.

Atmospheric Environment Service



Atmosphere - Ocean Interaction

During the Storm Transfer and Response Experiment (STREX) aircraft measurements of mean and turbulent meteorological parameters were made along "L" shaped tracks at several levels within the lower troposphere. From the mean data, after correcting for variations in the aircraft elevation along the track, it is possible to compute the geostrophic and thermal winds (theoretical winds due to pressure and density fields). These have been related to the vertical turbulent fluxes and the profiles of actual winds to aid in understanding and modelling atmospheric boundary-layer structure. During the STREX, simultaneous tracking of upper-air balloons was done by the NAVAID and radar windfinding systems. It was found that the two systems agreed well within the accuracies of either system. Since the NAVAID system is now being used on a volunteer observing ship between North America and Japan it was important to establish the relative accuracy of the system.

Three years ago, it was proposed at an international meeting that a large cooperative experiment be conducted to simultaneously estimate the meridional oceanic heat transport by three different techniques. The experiment, called Cage (because the techniques referred to used a measurement box or cage around the ocean basin), was to be done in the North Atlantic and/or North Pacific Oceans. An international study team, under the chairmanship of Dr. McBean and including Dr. A. Bennett, examined its feasibility and has recommended that it not be done because the probability of success was too small and that instead a coordination of ongoing or proposed programs be undertaken. (Contact: G.A. McBean.)

Precipitation Chemistry on the Pacific Coast

In order to ascertain the influence of industrial processes and urban areas on the chemistry of precipitation (principally the acidity), it is necessary to know the chemical composition in areas away from anthropogenic effects. A three-pronged measurement program has been started. Rain samples are collected at IOS. Rain samples are also collected on IOS cruises to Station P and to other areas. Snow samples have been collected at Mt. Washington and a helicopter survey to obtain snow cores in coastal mountains was undertaken. Through these data collection programs it is intended to determine the background marine chemical composition of rain/snow and to establish the representativeness of point measurements. (Contact: G.A. McBean.)



Splendor Mountain Lake—digging the pit.

Canadian Wildlife Service □ □ □

During 1982 work continued on preparation of an atlas showing the distribution and density of Canadian west coast bird populations. Publication is expected in early 1983.

Investigations of the Queen Charlotte Island archipelago seabird populations, conducted in 1982, will be continued in 1983. About one million seabirds nest in the Queen Charlotte Islands. Two species, the Ancient Murrelet and the Cassin's Auklet make up 77 percent of the seabird population there. Both species are small alcids and feed on zooplankton and larval fishes. The feeding strategies of the two alcids differ completely from one another. During breeding, the Cassin's Auklet acquires a throat pouch in which it brings food to its single chick in a nesting burrow at night. The chick is fed by the parents until seven weeks old, when it fledges and leaves the burrow for the sea. Unlike Cassin's Auklets, Ancient Murrelets do not develop a throat pouch and do not feed their young, but raise two chicks instead of one, and lead their two-day old and precocial chicks during darkness from their nesting burrow to the food source at sea. At sea, the parents remain with their chicks until they fledge.

Cassin's Auklet on the breeding ground.





Two-day old Ancient Murrelet chicks.



A pair of Ancient Murrelets.

The distribution of the two species on the nesting grounds as well as on the feeding areas at sea, will be investigated for the next few summers to determine the birds' requirements. Preliminary findings indicate that the Ancient Murrelets prefer to nest beneath mature canopies of Sitka spruce and western hemlock where undergrowth is scarce. Clearcut logging as practised in the Queen Charlotte Islands may destroy suitable Ancient Murrelet nesting habitat. Ancient Murrelets have not been found nesting in logging slash or regenerated forests. On the feeding areas at sea, both Ancient Murrelets and Cassin's Auklets may be vulnerable to potential oil spills from tankers between Alaska and Washington State, as well as to potential blowouts and leakages from drilling activities that are proposed offshore from the Queen Charlotte Islands. To determine the vulnerability of the small alcids to oil spillage, the Canadian Wildlife Service (CWS) will examine their distribution at sea. (Contact: K. Vermeer.)

**DEPARTMENT OF
ENERGY, MINES
AND RESOURCES**

Pacific Geoscience Centre



Pacific Geoscience Centre at IOS.

Earth Physics Branch and Geological Survey of Canada □□

Foreword □□□□□□□□□□□□□□□□

The purpose of the earth science programs within the Pacific Geoscience Centre is to collect geological and geophysical information on the evolution, the structure and the dynamic processes of the solid earth and the hazards associated with natural and induced geological processes. The western Canadian landmass and offshore regions are preferentially studied.

The projects described on the following pages have provided data for a number of aspects of these broad objectives. In particular, marine programs have provided data for the development and extension of ideas about contemporary and past plate motions along the western continental margin. These studies, coupled with expansions of the seismological network, levelling, and geodynamic surveys, are continually improving our understanding of earthquake mechanisms, frequency and risk. Systematic marine surveys in co-operation with the Hydrographic Service are also playing a vital part in providing a data base for the evolution and understanding of the mineral resources that may occur in Canada's western offshore areas.

Geothermal studies continued to explore and delineate alternative energy sources and to provide important scientific information about deep crustal structure. Gravity surveys in the Rocky Mountains continued as part of the long-term regional coverage of the northern Cordillera, now the principal remaining gap in the National Gravity Data set. Geological studies have been directed towards understanding of the history of the rock formations along the margin and of the deposition, composition and stability of sediments on the continental shelf and in coastal inlets. These studies provide input both into resource evaluation and into assessments of the environmental impact of the wide range of construction and development projects occurring along the coast and of offshore petroleum exploration.

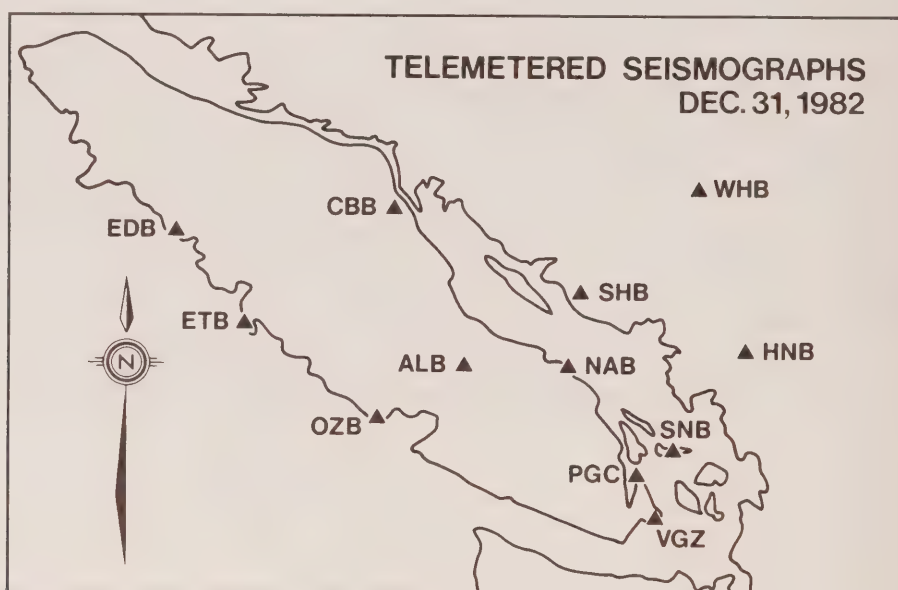
Seismological Service □□□□□□□□□□□□

The Seismological Service provides earth scientists, civil engineers, resource development industries and the public with basic earthquake data, and with research information concerning natural and induced earthquakes, ground motion, seismic risk, earth structure, and nuclear explosions. This is accomplished through a

network of seismological stations, including standard and regional stations, two telemetered arrays, strong motion accelerographs, and special installations.

Seismic Networks

The Western Canada Telemetered Network (WCTN), established to provide centralized, on-line monitoring of seismicity in southwestern British Columbia, was expanded in 1982 by three stations along the west coast of Vancouver Island and one station at the Gonzales Observatory in Victoria. Twelve stations were being recorded at the Pacific Geoscience Centre (PGC) by the end of the year. Preparatory site work was also completed for an additional site near Port Renfrew. The network located almost 200 small earthquakes in the Vancouver Island – Strait of Georgia region in 1982. (Contact: D.H. Weichert, G.C. Rogers, M. Bone, A. Whitford.)



The West Coast Telemetered Network (WCTN) for earthquake monitoring currently comprises 12 seismic stations whose signals are transmitted to a central computer at PGC. Automatic monitoring of these signals permits virtually on-line location of seismic events in southwest British Columbia.

The strong motion seismograph network in western Canada, which consists of instruments designed to operate and record ground acceleration only when very strong ($\frac{1}{2}\%$ of normal gravity or larger) earth motion occurs, remained at 33 accelerographs, although some site changes were made. During 1982, PGC personnel coordinated the reduction and the publication of the strong motion records from the New Brunswick earthquakes. (Contact: D.H. Weichert, H. Bennetts.)

Staff at the Pacific Geoscience Centre updated catalogues to provide the time and location of earthquakes occurring in western Canada. For the first half of 1982, about 300 earthquakes have been added to the catalogue. (*Contact: R. Horner.*)

Special Earthquake Studies

The separate cooperative projects with Dome Petroleum Ltd. and B.C. Hydro and Power Authority, in order to monitor earthquake activity for local seismic risk estimates in the Beaufort Sea region and in northern British Columbia, continued in 1982. The seismograph records are sent to PGC for analysis. (*Contact: D.H. Weichert; G.C. Rogers.*)

Three new regional seismic stations were commissioned in Ocean Falls, Cape St. James and in Tasu, to improve the coverage of the Queen Charlotte Island area. (*Contact: D.H. Weichert.*)

Revision of the epicentres of earthquakes occurring in the Queen Charlotte Islands region has been done. Almost all earthquakes have epicentres close to the Queen Charlotte fault with no evidence that significant earthquakes have occurred in Hecate Strait or Queen Charlotte Sound in historic time. The revised seismicity pattern plus microearthquake observations on the Queen Charlotte Islands suggest that there is little seismicity on other major fault systems to the east of the Queen Charlotte fault. During 1982 only one magnitude $3\frac{1}{2}$ event occurred on the east side of Hecate Strait and one magnitude 4 event occurred on the fault near Masset, Queen Charlotte Islands.

The focal mechanisms of earthquakes along the Queen Charlotte fault suggest the fault is not a pure transform at its southern end but has an element of convergence across it.

The distribution of large earthquakes and their aftershocks along the Queen Charlotte fault indicate the existence of a seismic gap just south of the Queen Charlotte Islands which would require an earthquake the order of magnitude 7 to fill it. (*Contact: G.C. Rogers.*)

A microseismicity study in the St. Elias region has been completed. The most active zone of seismicity follows the Pacific-America plate boundary along the coast of Alaska. A less active zone follows the Denali fault system through the southwest Yukon, but it does not continue into Chatham Strait. Instead, it turns south into the Glacier Bay region to connect with the Fairweather fault. (*Contact: R.B. Horner.*)

Seven strong motion recorders were installed in the epicentral area of the 1982 New Brunswick earthquake series. Twelve records were obtained. Peak ground acceleration ranged from a few percent to many tens percent of the gravitational acceleration constant. Dominant frequencies of the records are high (25 Hz and more) so that ground velocities are only a few cm/s, consistent with the observed intensities. (*Contact: D.H. Weichert.*)

A synthesis of seismic refraction and multi-channel reflection data from the Winona sedimentary basin off northern Vancouver Island has demonstrated that Pleistocene turbidite sediments have seismic velocities in excess of 5 km s⁻¹. Extremely rapid de-watering and diagenesis can explain these unusual velocities. (Contact: E.E. Davis.)

A compilation of magnetic, bathymetric, photographic, seismic reflection and dredged sample data has revealed the nature of the propagating offset on the Juan de Fuca Ridge at 47°30'N. The ridge is currently spreading along a continuous curved centre, which connects the northern and southern straight ridge segments. (Contact: E.E. Davis.)

Seismic Risk Estimation

The Pacific Geoscience Centre provides site specific risk estimates for many engineering projects in western Canada. New risk maps were completed in 1982, which will be incorporated in the 1985 National Building Code of Canada. (Contact: D.H. Weichert.)

☐ ☐ ☐ ☐ ☐ Geothermal Studies ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

The earth's temperature influences both rock properties and geological processes. Thermal data, particularly surface heat flux, are among the most important indicators of deep tectonic processes and the structure of the earth's crust. Most active tectonic processes that result in mountain building, earthquakes and volcanism originate from thermal energy. In addition, the earth has considerable economic potential as a heat source for geothermal energy.

Measured thermal parameters include surface heat flux (the result of vertical temperature gradient multiplied by the thermal conductivity of the rocks), and heat production from natural radioactive decay in crustal rocks (for example: thorium and potassium). Studies cover a wide range of geological and geophysical interests — from heat flow, heat production and thermal processes in the deep sea floor, to the discovery and development of geothermal energy resources in western Canada.

Land Studies

There is a continuing program to determine the regional geothermal heat flow pattern from borehole measurements in the Canadian Cordillera. These data can be used in the interpretation of regional tectonics and structure, and in the delineation of hot areas with potential for geothermal energy development. In south central British Columbia, the heat flow measured in shallow holes along a 200 km profile

across the Okanagan Highlands is remarkably uniform at 75 mW m⁻². Measurements are being completed in additional shallow holes in the Garibaldi and the Alert Bay Volcanic Belts. (Contact: E.E. Davis, T.J. Lewis.)

A gamma-ray spectrometer is used to measure the heat generation in samples of rock. A new PDP-11/23 computer was interfaced to the 7010 EG & G spectrometer and several hundred samples were measured. The mine tailings from the Amax mine in Alice Arm have less radioactivity than many normal surface rocks, including the outcrops sampled on Alice Arm. The average heat generation of Scotian Shelf sediments cause the temperature at the bottom of the basement to be 17°C higher than if there were no heat generated within the basin.

Marine Studies

A series of repeat marine-probe, heat-flow measurements have been carried out up the length of Jervis Inlet to investigate further the previously observed increase of heat flow as the Garibaldi Volcanic Belt is approached. The large increase in heat flux by a factor of two is observed to take place near the head of the Inlet over a distance of 20 km. The bottom sediments of Bute Inlet were found to be too hard to penetrate with long oceanographic heat-flow probes. (Contact: T.J. Lewis.)

Further northward in Queen Charlotte Sound, a suite of cores and heat-flow measurements have shown that coarse-grained and over-consolidated sediments are pervasive as a result of Holocene non-deposition and submarine erosion. Variations of bottom water temperature preclude the measurement of reliable heat flow with penetrations of only 9 cm. (Contact: E.E. Davis.)

The thermal regime of the Queen Charlotte fault zone area and Queen Charlotte Basin was examined through ocean probe, petroleum-exploration well temperatures and thermal conductivity data. Thermal models were developed for an underthrusting oceanic lithosphere and a margin rift. (Contact: R.D. Hyndman, T.J. Lewis, C.J. Yorath.)

The heat flow and hydrothermal regime in a Deep Sea Drilling Project (DSDP) deep-ocean crustal borehole on the mid-Atlantic ridge has been examined. The heat flow measured in the deeper part of the hole is high, very close to the theoretical cooling lithosphere value.

A review of all heat flow measurements obtained in deep boreholes by the DSDP ship *Glomar Challenger* has been prepared. The study confirmed that shallow heat probe measurements generally provide nearly as reliable heat flow data as the deeper borehole measurements except near ridge crests. A compilation of all geothermal heat flow values offshore and onshore for the area covered by the Juan de Fuca Plate map sheet has also been completed. (Contact: R.D. Hyndman.)

An analysis of four suites of closely spaced heat flow sites in the Jurassic of Northwestern Atlantic has been done. The heat flow from lithosphere ranging in age from 110 to 155 Ma is uniform and high. Boundary-layer cooling or plate

cooling does not explain these results. A reheating of the lithosphere can account for the high heat flow values. (Contact: E.E. Davis.)

□ □ □ □ □ Gravity □ □ □ □ □ □ □ □ □ □ □ □ □ □ □

The principal task of the Gravity service is to establish the shape of the geoid in Canada to the highest standards and to determine the value of gravity on a regional basis over the Canadian landmass and offshore areas. The geoid is the reference surface for all surveying and mapping. The regional gravity data provide information for both the determination of crustal structure and the evaluation of resources and are critical to the operation of inertial navigation systems used by defence agencies for submarines and missiles.

Seaborne operations in 1982 aboard CSS *Parizeau* covered an area of 35,000 km² on a systematic 10 km line spacing out to the 200 nautical mile limit southwest of the Queen Charlotte Islands. Two La Coste and Romberg dynamic gravimeters were operated simultaneously: SL1, the "linear" prototype meter tested in 1980 and a three-axis "beam" meter, S56. Comparison of the two systems again showed that the linear meter performed with greater accuracy. In particular, because of the reduction of cross-coupling due to ship movement, it was more tolerant of rough water.

The 1982 survey will be integrated with the continuing series of regional offshore surveys for release in 1983. Two extended lines of 400 km length were surveyed out to 137°W in an attempt to locate magnetic anomaly 6 (20 Ma old) and check the existence of a proposed "pseudo fracture zone".

Land regional gravity surveys by helicopter were completed in 1982 under contract in an area between Jasper and Prince George by Terra Surveys Ltd. As in previous years, a combination of existing monumentation and inertial navigation was used to provide the required ± 50 m horizontal and ± 3 m vertical control. Two hundred and eighty new stations were observed. (Contact: R.P. Riddihough, D. Seemann.)

□ □ □ □ □ Geodynamics □ □ □ □ □ □ □ □ □ □ □ □ □

The principal subject of study for geodynamics in the active tectonic regions of Canada's west coast is contemporary crustal deformation. One objective of this research is to establish realistic dynamic models of crustal plate behaviour and utilize these in the study of earthquakes.

Efforts to measure crustal strain continue to be concentrated in central Vancouver Island near the epicentral region of the 1946 earthquake. Precise gravity surveys and repeated vertical control surveys over the past year indicate irregular aseismic vertical deformation of the order of 1 cm/a accompanied by significant

local mass changes most likely due to groundwater injection or withdrawal in fracture zones.

A nine-station triangulation network established in 1947 in the Gold River area was resurveyed using laser-ranging instrumentation. Precisions of 3 parts in 10^7 were obtained over line-lengths of up to 40 km. Future resurveying of this network will provide a measurement of present-day horizontal crustal strain in this critical region which straddles the landward extension of the Nootka Fault zone.

Preparatory work for the measurement of relative crustal deformation over baselines of thousands of kilometers using VLBI (Very Long Baseline Interferometry) was continued. Reconnaissance for site locations for NASA's 4 m 'portable' radio antenna was carried out in Yellowknife, N.W.T., and in Whitehorse, Y.T. Local geodetic networks were established in each locale for future site stability measurements. The first horizontal control survey of the local geodetic network containing the proposed VLBI site at Penticton, B.C., was completed in August. (Contact: H. Dragert.)



The measurement of small changes in elevation over periods of a few years is extremely difficult especially in regions with limited road access. Using very sensitive gravimeters transported by helicopters or float-aircraft, vertical strain measurements can be carried out over long distances in the rugged terrain of Canada's west coast.

The Geomagnetic Field

The earth's geomagnetic field varies both spatially and temporally. This inherent variability of the geomagnetic field is exploited in a variety of ways. To be utilized for navigation, the magnetic field and its gradual change with time must be determined as a function of latitude and longitude. Changes in the magnetic properties of rocks also lead to spatial variations in the magnetic field which become characteristic signatures of structure, composition, and the thermal history of crustal rocks. Short-period temporal changes in the magnetic field must be monitored in order to resolve subtle spatial field variations as encountered in exploration geophysics.

In Canada, the geomagnetic field is monitored continuously at 13 primary observatory sites and discontinuously at about 140 secondary sites. As part of this Canadian Geomagnetic Network, the Pacific Geoscience Centre operates the Victoria Geomagnetic Observatory (VGO) on property near the Dominion Astrophysical Observatory.

The Pacific Geoscience Centre also collects magnetic field observations at the 15 repeat stations in British Columbia. These data are used in updating maps of the geomagnetic field components for the Canadian land mass every 5 years. During the summer of 1982, measurements were obtained at 2 of these sites.

Geomagnetic Variations

Temporal variations in the earth's magnetic field provide a source of electromagnetic energy with which to probe the earth's electrical conductivity structure. Zones of high conductivity, if related to high temperatures and partial melting, can be used to define areas of geothermal interest. Geomagnetic depth-sounding can also determine the thickness of the cold lithospheric plate riding over the asthenosphere, an important parameter in understanding the active tectonic regions dominant on the west coast.

Confirmation that the cold Juan de Fuca lithospheric plate does indeed dip beneath the continental mass under Vancouver Island has been derived from an analysis of the geomagnetic data obtained in a 1980 experiment. A finite difference approximation of Maxwell's equations for a model consisting of a descending lithosphere beneath Vancouver Island predicted quite closely P.G.C.'s observations across the continental margin.

Ocean bottom magnetometers (OBM) were recovered, after a 33 day recording period, from 3 sites across Queen Charlotte Sound to the abyssal plains west of the Sound. The vertical magnetic field recorded at the base of the slope was far greater than those at the shelf or the deep site. The enhancement of the vertical field may be due to the proximity of the site to the Queen Charlotte transform fault zone.

The injection of electric current into the sea floor via a vertical cable from a ship produces magnetic fields that can be measured with OBM's. At the Queen Charlotte Sound site, on the shelf (200 m depth), this procedure was further tested, with successful recordings of signals out to 10 times the vertical water depths. This result confirmed that a deep ocean (3 km say) experiment should give signals sufficient to probe the conductivity structure of the oceanic lithosphere (to 30 km).

In order to determine the conductivity structure beneath Vancouver Island more precisely, many samples of variations in the electromagnetic field components are required. In 1982, about 40 days of recordings were obtained at the two standard sites in central Vancouver Island. Repeated observations at these sites will be done in the future in order to monitor possible temporal changes in crustal conductivity structure. (Contact: L. Law, J. DeLaurier, D. Auld.)

Paleomagnetism

The paleomagnetism of rocks records the variations in directions of the geomagnetic field in the geological past. The intensity of the ancient field is also recorded but is more obscure and difficult to observe and can only be obtained in very favourable circumstances. The principal application of paleomagnetism is in tectonics — the study of the motion of continents, the opening and closing of oceans and the origin of mountain belts — but it is also used widely in many problems of stratigraphic correlation, the origins and thermal history of rocks, and in the source and origin of magnetic anomalies.



The paleomagnetic laboratory currently being installed at PGC included two microprocessor controlled spinner magnetometers used to measure the remanent magnetic fields in rock samples. The raw data are communicated directly to the mainframe computer for analysis.

The new paleomagnetic laboratory at PGC is nearly complete. Work will be related mainly to studies of the tectonics of the Cordillera and the western Arctic and to magnetostratigraphic studies. During the last decade, geological and geophysical studies have shown that the Cordillera comprises a number of distinct crustal blocks. Vancouver Island is one such block. Paleomagnetic work has shown that these blocks have been transported from the south by distances over 1000 km, much of central British Columbia once being in the latitude of California. Vancouver Island could have moved northward by over 5000 km relative to North America and may even have originated on the other side of the Pacific Ocean. The western Cordillera, therefore, appears to be a collage of small crustal fragments that originated elsewhere, were carried over large distances, and finally glued to North America. This discovery has led to a profound revision of our ideas about the origin of this and other mountain belts.

Two major programs were initiated. The objective of the first is to collect a suite for a traverse across the Cordillera from Vancouver Island to the Rockies in order to determine the relative latitudes of the various crustal elements at one geological instant in time; namely the Middle Cretaceous epoch near 100 Ma ago. The second program calls for a traverse across the northern rim of the Sverdrup Basin in Ellesmere Island. Results show an unexpected 30° anticlockwise rotation which may reflect strain distributed across northern Ellesmere Island and may be associated with the opening of Baffin Bay. (Contact: E. Irving.)



Arctic Tectonics



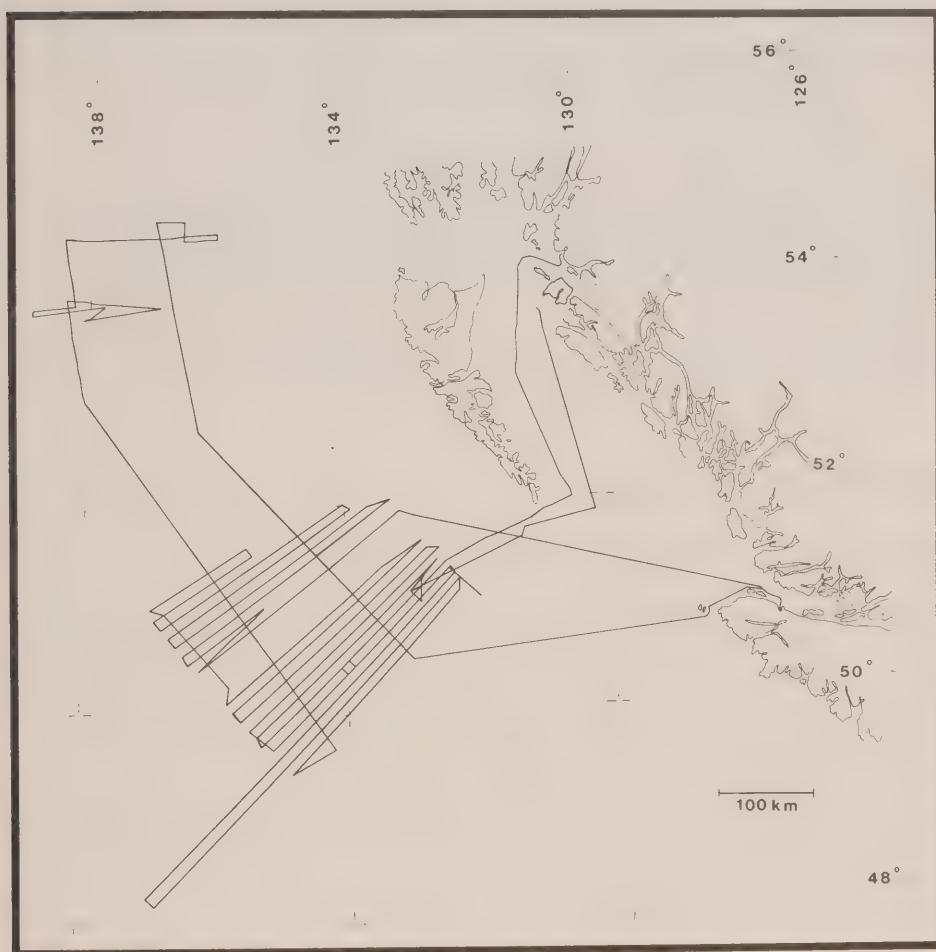
Two new ideas about Arctic tectonic history have been suggested. The first suggests that the mid-Paleozoic Ellesmerian orogeny in the Arctic Islands was produced when a continental terrane that included northern Alaska was displaced southwestwards by as much as 2000 km from its initial orogenic site to the north and east of Ellesmere Island. The second idea is that the Lomonosov Ridge was sheared from the polar margin of western Eurasia, probably in Late Cretaceous time, along a trans-Arctic left-lateral offset that may have been related to the opening of Baffin Bay. The Eurasia Basin was opened later, in early Tertiary time, when the North Atlantic rift extended into the Arctic region and separated the Lomonosov Ridge from Eurasia.

An Arctic volume contribution to the series "Geology of North America" has been specified and publication is expected in 1985. The editors have published a regional overview and have selected the contributors. The North American Continent — Ocean Transects Program consists of 23 margin studies in progress around the continent. One of these is in the Arctic; the cross-section sheets and the pertinent manuscripts are nearly completed for publication in 1984. (Contact: J.F. Sweeney.)

Geological - Geophysical Studies



Systematic magnetic, gravity and bathymetric surveys are being conducted over the Canadian Economic Zone to help assess the economic potential of the region and its tectonic framework. The 1982 survey in this Resource Mapping program was conducted between 180 and 360 km west of the Queen Charlotte Islands (approx. 50°N to 54°N). Continuous magnetic, gravity and bathymetric data were collected in 770 km of survey and tie lines in this previously unsurveyed area of the northeast Pacific. The new magnetic data fills a gap between the *Pioneer* data to the south and early Pacific Geoscience Centre surveys to the north. In addition, a test line was run to approximately 550 km offshore in an attempt to place limits on the position of a propagating rift trace. (Contact: R. Currie.)



The ship's track lines for the 1982 Resource Mapping Survey west of Queen Charlotte Islands.

Geological studies on the Queen Charlotte Islands and concurrent geophysical programs in Hecate Strait and Queen Charlotte Sound have led to new interpretations of the tectonic history and petroleum potential of the Queen Charlotte Basin. The recognition of the origin and timing of collision of exotic crustal fragments and the rift origin of Queen Charlotte Sound has permitted new geophysical modelling of the dynamics and thermal history of the basin. Two possible sources of hydrocarbons are indicated. The first is related to the possible occurrence of petroliferous Upper Triassic and Jurassic rocks beneath southern Hecate Strait similar to those observed on the Queen Charlotte Islands. Rifting in Queen Charlotte Sound possibly has allowed these older hydrocarbons to migrate upward along faults to become trapped within the Tertiary sediments. The second source for hydrocarbons lies within the tertiary sediments themselves. The subsidence and thermal history of the basin suggest that sufficient metamorphism of organic matter would have occurred. If petroleum source rocks are eventually found, favourable reservoir rocks within the basin may contain liquid hydrocarbons of Tertiary age. (Contact: C.J. Yorath).



Paleontology



Activities in Paleontology at the Pacific Geoscience Centre are focussed on micropaleontological biostratigraphy of Mesozoic and Cenozoic rocks of the complex Pacific margin of Canada. Work is continuing in studies of Tertiary biostratigraphy both on land and offshore with emphasis on depositional environments and planktonic foraminifers. Ultimately this study should assist in understanding the tectonic evolution of the west coast and its potential for oil and gas exploration. (Contact: B. Cameron.)



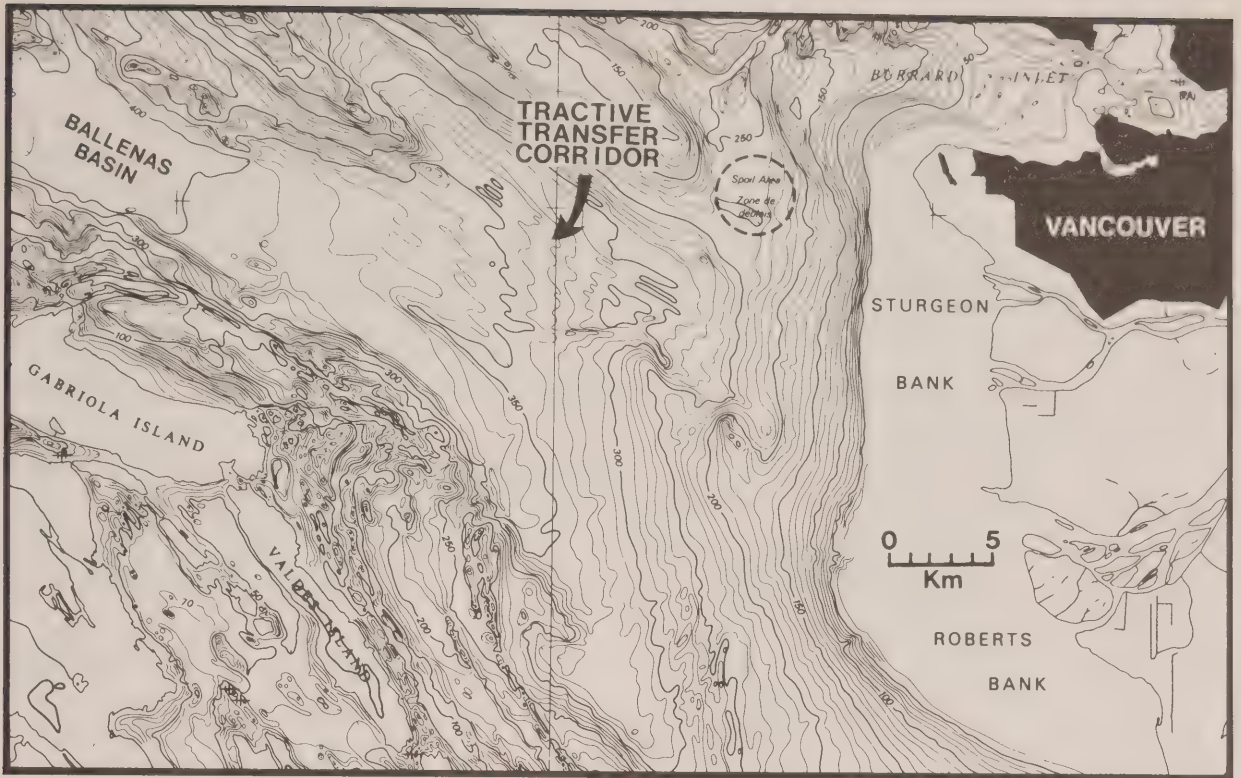
Sedimentology



Estuarine and Marine Delta Sedimentation

As in previous years demand has remained high for geological data from the Fraser River delta which can help formulate environmental/engineering guidelines. Results of geological research have been applied to investigations by outside agencies relating to the proposed Iona Island sewage pipeline, Westshore Terminals coalport expansion and B.C. Hydro proposed Vancouver Island gas pipeline.

Research has focused on defining the influence of deltaic processes on the adjacent Strait of Georgia seafloor and elucidating the major stages of Fraser River delta evolution. (Contact: J.L. Luternauer.)



The tractive transfer corridor has been identified as the major pathway for turbidity/density currents originating at the Sturgeon Bank (Fraser River Delta) slope. Contours in metres. (Base Map: Canadian Hydrographic Service Natural Resource Map 15792-A)

Coastal Studies

Coastal sedimentology and geomorphology are studied to (i) provide a data base for port location, industrial development, and shoreline management and recreation, (ii) develop oil spill contingency plans including an assessment of the fate and behaviour of oil in the coastal zone and cleanup techniques and, (iii) elucidate the geological evolution of British Columbia's coastline.

To achieve these aims, six locations throughout the Strait of Juan de Fuca, the Gulf Islands and the Strait of Georgia were chosen, each location containing a variety of environments representative of the coast. About 500 sediment samples were collected for sediment textural analysis which, when complete, will provide not only a description of each of the facies encountered in the beach and nearshore zones, but also the basis for understanding the sedimentary dynamics of the coastline. In addition to sampling, beaches and nearshore environments at each location were surveyed, the latter with both an echo sounder and a sub-bottom

profiler. A SCUBA program enabled first-hand observation of the submarine environments.

These surveys are used to develop a process-response model to describe the evolution of the beach nearshore system within the Strait of Georgia. The nearshore profile develops a characteristic shelf form. The width of the shelf and depth of water at the shelf break increase with exposure to wave energy. Statistical relationships between the wave climate, shelf morphology, and sediment distribution provide a model of the shelf as an equilibrium size-graded form, similar to prograding shelves on the continental margins. (*Contact: P. McLaren.*)

APPENDIX I

Contracts Awarded 1982/83

<i>Depth Sounder Frequency Synthesizer</i> Analytic Systems Ware Ltd., Vancouver, B.C. . . \$	1,672	<i>Study of the Theory of Flow Over Sill</i> B.L. Blackford, North Saanich, B.C.	15,000
<i>Collection and Analysis of Alice Arm Zoo-plankton Samples</i> Edward Anderson Marine Sciences, Victoria, B.C.	19,000	<i>Identification and Enumeration of Zooplank-ton Samples</i> Broccoli Bros. Enterprises Inc., Sidney, B.C.	8,000
<i>Contract Monitoring System</i> Anthony Macauley Associates Ltd., Victoria, B.C.	8,150	<i>Ship of Opportunity Sampling of the Plankton-ic Ecosystem Off the Pacific Coast of Canada</i> Broccoli Bros. Enterprises Inc., Sidney, B.C.	51,603
<i>To Study the Impact of a Lead-Zinc Mining Operation on the Marine Environment of Strathcona Sound, N.W.T.</i> Arctic Laboratories Ltd., Yellowknife, N.W.T.	1,500	<i>Development of a Fibre Optic Interferometer with Applications to Sensors Communications and Laser Instrumentation</i> Canadian Instrument & Research Ltd.	272,794
<i>Analysis of Surficial Marine Sediment</i> Arctic Laboratories Ltd., Sidney, B.C.	17,500	<i>The Sedimentation of Mine Tailings in a Marine Environment (Phase I)</i> Capital Applied Research (Retch), Victoria, B.C.	38,382
<i>Study of the Long-term Mobility of Discharged Drilling Fluids in the Beaufort Sea</i> Arctic Laboratories Ltd., Sidney, B.C.	15,810	<i>Development of a Methodology to Determine Bio-accumulation and Sub-lethal Toxicity into the Food Web of Ocean Dumped Material using a Polychaete Worm and a Benthic Flatfish</i> Dobrocky Seatech Ltd., Sidney, B.C.	86,901
<i>Preparation of Draft Report on Beaufort Sea Zoobenthos Data Compilation</i> Arctic Laboratories Ltd., Sidney, B.C.	6,418	<i>Analysis and Interpretation of Oceanographic Data from Bridport Inlet, Melville Island, N.W.T.</i> Dobrocky Seatech Ltd., Sidney, B.C.	14,000
<i>Compilation and Appraisal of Existing Chemical Oceanographic Data in the Northwest Passage</i> Arctic Laboratories Ltd., Sidney, B.C.	39,705	<i>Boat Charter</i> J. Egeland Fish Co., Sooke, B.C.	46,360
<i>Development of Computer Software Related to Data Inventory Studies of the Beaufort Sea, Northwest Passage and Arctic Islands</i> Arctic Sciences Ltd., Sidney, B.C.	9,421	<i>Computer Software</i> Empirical Research Group Inc., Milton, Wn.	9,951
<i>Preparation and Reformat of Beaufort Sea Physical Oceanographic Data for Archiving</i> Arctic Sciences Ltd., Sidney, B.C.	25,624	<i>Assessment of Environmental Reviews and Data Reports for the West Coast and Beaufort Sea</i> Environmental Sciences Ltd., Vancouver, B.C. . . .	10,000
<i>Continuation of a Synoptic Aircraft-Based Oceanographic Survey in the Arctic Archipelago</i> Arctic Sciences Ltd., Sidney, B.C.	113,593	<i>Compilation, Review and Assessment of Major Environmental Assessment Reports and Atlases for the West Coast of British Columbia</i> Environmental Sciences Ltd., Vancouver, B.C. . . .	5,000
<i>Development of Computer Software for Contouring Field Hydrographic Data</i> Barrodale Computing Services Ltd., Victoria, B.C.	171,150		

<i>Identification and Enumeration of Marine Phytoplankton</i> E.V.S. Consultants Ltd., North Vancouver, B.C. ..	5,978
<i>Benthic Studies in Alice Arm and Hastings Arm, B.C. in Relation to Mine Tailings Dispersal; Part II, Biological Analysis</i> E.V.S. Consultants Ltd., North Vancouver, B.C. ..	21,361
<i>Size Estimates of Phytoplankton Species</i> E.V.S. Consultants Ltd., North Vancouver, B.C.	596
<i>Oceanographic Observations Aboard CFAV Endeavour</i> H. Goldberg, Vancouver, B.C.	1,200
<i>HF SSB Radio System</i> Harris Corporation, Rochester, N.Y.	14,792
<i>Investigation of Arctic Industrial Offshore Activities and Ocean Dredging and Dumping in B.C. Coastal Waters</i> R.H. Herlinveaux, North Saanich, B.C.	31,950
<i>Coordination and Publication of a Summary and User's Guide and Brochure for the Arctic Marine Data Compilation and Appraisal Series</i> Hoot Productions Ltd., Victoria, B.C.	8,600
<i>Development of Computer Programmes for Processing Studies in Ocean and Atmospheric Physics</i> Interact Computing Services Ltd., Sidney, B.C. ..	21,129
<i>Development of Computer Programme for Analysis of Oceanographic Data from Prince of Wales Strait, Viscount Melville Sound and M'Clure Strait</i> Interact Computing Services Ltd., Sidney, B.C. ..	40,244
<i>Design of Two Deep-Sea Oceanographic Mooring Systems</i> T. Juhasz, Victoria, B.C.	5,587
<i>Compilation and Collation of Tsunami Records</i> M. Lane, Victoria, B.C.	3,045
<i>Horizontal Control Survey for a Planned Hydrographic Survey off the Yukon Coast, West of Hershel Island to the Alaska Border</i> McElhanney Surveying & Engineering Ltd., Calgary, Alta.	57,360
<i>MSI - H-Series Development</i> Meyer Systems Ltd., Vancouver, B.C.	120,000
<i>Tsunami Data Computer Programming</i> M.M. Nugent, Victoria, B.C.	1,980
<i>Analysis of Southern Hemisphere Drifting Buoy Data</i> Odysseas Ocean Sciences Ltd., Victoria, B.C.	18,850
<i>Analysis of FGGE Drifting Buoy Data</i> Odysseas Ocean Sciences Ltd., Victoria, B.C.	7,875
<i>Oceanographic Analyses of Sediment and Water Samples from Alice Arm, British Columbia</i> M. Paryniuk, Victoria, B.C.	26,595
<i>Analysis of Tsunami Potential of Landslides</i> D. Philip, Victoria, B.C.	5,040
<i>Construction and Testing of Five Floating Ice Pressure Drums</i> Polar Tech Ltd., North Saanich, B.C.	50,000
<i>Analysis of Marine Air Samples from Weather-ships and Other Cruises</i> W. Richardson, Victoria, B.C.	6,200
<i>Analysis of Subsea Containment and Free Plume Test</i> R.D. Rowe, Calgary, Alta.	12,000
<i>Ocean Ecology Research Support to the Institute of Ocean Sciences</i> S & B Research Ltd., Victoria, B.C.	4,850
<i>Compilation and Interpretation of Marine Meteorology and Precipitation Chemistry Data</i> S & B Research Ltd., Victoria, B.C.	15,925
<i>Compilation and Interpretation of Marine Meteorology and Precipitation Chemistry Data</i> S & B Research Ltd., Victoria, B.C.	14,450
<i>Oceanographic Data Collection of the Coastal Waters of British Columbia</i> S & B Research Ltd., Victoria, B.C.	15,000
<i>Sidescan Development</i> Sea I Research, Patricia Bay, B.C.	2,800
<i>Analysis of Sediment Trap Material</i> Seakem Oceanography Ltd., Sidney, B.C.	3,450
<i>A Study of Sediment and Tailings Transport in Alice Arm, B.C.</i> Seakem Oceanography Ltd., Sidney, B.C.	52,283
<i>Analysis of Extracts of Seawater for Ultra-trace Metals by Mass Spectrometry</i> Seakem Oceanography Ltd., Sidney, B.C.	10,174
<i>Analysis of Seawater and Marine Air Samples from Weatherships and Other Cruises</i> Seakem Oceanography Ltd., Sidney, B.C.	71,877

<i>Oceanographic Data and Scientific Analysis Concerning the Canada/Germany Project Flurex '82</i>		<i>Survey and Literature Review of the Chemistry of Halocarbons</i>	
Seakem Oceanography Ltd., Sidney, B.C.	28,800	University of Victoria, Chemistry Department .	7,134
<i>Compilation and Collation of Tsunami Records</i>		<i>Evaluation of High Resolution Frequency Analysis Techniques Applicable to Doppler Sonar Operations</i>	
P. Straub, Sidney, B.C.	3,995	University of Victoria	1,500
<i>To Conduct Hydrographic Surveys over Selected Artificial Island Sites in the Beaufort Sea</i>		<i>Design, Furnish and Install a Computed Line Steering System</i>	
Terra Surveys Ltd., Patricia Bay, B.C.	62,813	Walker Industrial Computing, Patricia Bay, B.C. ..	9,705

APPENDIX II

Publications

A. Department of Fisheries and Oceans

(1) Canadian Data Report of Hydrography and Ocean Sciences

No. 3	Hill, S., K. Denman, D. Mackas and H. Sefton	<i>Ocean Ecology Data Report: Coastal Waters off Southwest Vancouver Island. Spring and Summer 1979</i>
No. 4	Hill, S., K. Denman D. Mackas and H. Sefton	<i>Ocean Ecology Data Report: Coastal Waters off Southwest Vancouver Island. Spring and Summer 1980</i>
No. 5 Volume 1	Cornford, A.B., D.D. Lemon, D.B. Fissel, H. Melling, B.D. Smiley, R.H. Herlinveaux and R.W. Macdonald	<i>Arctic Data Compilation and Appraisal. Beaufort Sea: Physical Oceanography — Temperature, Salinity, Currents and Water Levels</i>
No. 5 Volume 2	Thomas, D.J., R.W. Macdonald and A.B. Cornford	<i>Arctic Data Compilation and Appraisal. Beaufort Sea: Chemical Oceanography</i>

(2) Canadian Technical Report of Hydrography and Ocean Sciences

No. 3	Henry, R.F.	<i>Automated Programming of Explicit Shallow-Water Models. Part I. Linearized Models with Linear or Quadratic Function</i>
No. 7	Perkins, R.G. and E.L. Lewis	<i>Design of CTD Observational Programmes in Relation to Sensor Time Constants and Sampling Frequencies</i>
No. 8	Ages, A.	<i>The Development of an Oilspill Tracking Technique</i>

(3) Canadian Contractor Report of Hydrography and Ocean Sciences

- No. 3 Byers, S.C. and G.S. Calderwood (eds.), Dobrocky Seatech Ltd. *Report on Ocean Dumping R & D Pacific Region Department of Fisheries and Oceans 1980-1981*
- No. 5 Nicoll, M. (Interact Computing Services Ltd.) and D.J. Stucchi *Alice Arm 1981 CTD Data Access Guide*

(4) Other Publications, 1982

- ABBOTT, M.R., P.J. RICHERSON and T.M. POWELL. 1982. *In situ* response of phytoplankton fluorescence to rapid variations in light. *Limnol. Oceanogr.*, **27**(2):218-225.
- BAKER, H.R. 1982. A note on the genitalia of *Potamothrix hammoniensis* (Oligochaeta: Tubificidae). In: *Proc. Biol. Soc. Wash.*, **95**:563-566.
- BAKER, H.R. and C. ERSÉUS. 1982. A new species of *Bacescuella* Hrabe (Oligochaeta, Tubificidae) from the Pacific Coast of Canada. *Can. J. Zool.*, **60**:1951-1954.
- BENNETT, A.F. and P.C. MCINTOSH. 1982. Open ocean modelling as an inverse problem: tidal theory. *J. Phys. Oceanogr.*, **12**:1004-1018.
- BENNETT, A.F. and P.E. KLOEDEN. 1982. The periodic quasigeostrophic equations: existence and uniqueness of strong solutions. In: *Proc. R. Soc. Edin.*, **91A**:185-203.
- BOLTON, M. 1982. Hydrography, a perspective. In: *Proc. CIS Centennial Convention, April 19-23, 1982*.
- BRINKHURST, R.O. 1982. Evolution in the Annelida. *Can. J. Zool.*, **60**:1043-1059.
- BRINKHURST, R.O. 1982. Additional aquatic Oligochaeta from Tasmania. *Rec. Queen Victoria Mus.*, **78**:1-16.
- BRINKHURST, R.O. 1982. British and other marine and estuarine Oligochaetes. In: *Synopses of the British Fauna*, Doris M. Kermack and R.S.K. Barnes (eds.), Cambridge Univ. Press, **21**: 123 pp.
- BRINKHURST, R.O. 1982. Review of four new journals. *Can. J. Fish. Aquat. Sci.*, **39**:1073-1074.
- BRINKHURST, R.O. 1982. Oligochaeta. In: *Synopsis and Classification in Living Organisms*, S.P. Parker (ed.), McGraw Hill, New York, 50-61.
- BRINKHURST, R.O. 1982. On the types of Tubificidae (Oligochaeta) described by W. Michaelsen and others in the Zoological Institute and Zoological Museum, University of Hamburg. *Mitt. Hamb. Zool. Inst.*, **78**:7-17.
- CARMACK, E. and D. FARMER. 1982. Cooling processes in deep, temperate lakes: a review with examples from two lakes in British Columbia. *Journal of Marine Research*, **40**:Sup.:85-111.

- CHAPMAN, P.M., M.A. FARRELL and R.O. BRINKHURST. 1982. Relative tolerances of selected aquatic Oligochaetes to individual pollutants and environmental factors. *Aquat. Toxicol.*, **2**:47-67.
- CHAPMAN, P.M., M.A. FARRELL and R.O. BRINKHURST. 1982. Relative tolerances of selected aquatic Oligochaetes to combinations of pollutants and environmental factors. *Aquat. Toxicol.*, **2**:69-78.
- CHAPMAN, P.M., M.A. FARRELL and R.O. BRINKHURST. 1982. Effects of species interactions on the survival and respiration of *Limnodrilus hoffmeisteri* and *Tubifex tubifex* (Oligochaeta, Tubificidae) exposed to various pollutants and environmental factors. *Water Research*, **16**:1405-1408.
- CRAWFORD, W.R. 1982. Analysis of fortnightly and monthly tides. *Int. Hydrog. Rev.*, LIX(1).
- CRAWFORD, W.R. 1982. Pacific equatorial turbulence. *J. Phys. Oceanogr.*, **12**:1137-1149.
- CRAWFORD, W.R. and R.E. THOMSON. 1982. Continental shelf waves of diurnal period along Vancouver Island. *J. Geophys. Res.*, **87**:CL9516-9522.
- DENMAN, K.L., H.J. FREELAND and D.L. MACKAS. 1982. An upwelling gyre off the west coast of Vancouver Island. *Lighthouse*, **26**, :7-9.
- DENMAN, K.L. 1982. Book review of *Mixing in Inland and Coastal Waters* by H.B. Fischer, E.J. List, R.C.Y. Koh, J. Imbarger and N.A. Brooks, Academic Press Inc., New York. In: *Limnology and Oceanography*, **27**:593-594.
- EATON, R.M., M. McALONEY, A. MORTIMER, E. SHENING and B. WALDOCK. 1982. Beaufort Sea Loran-C tests. *Canadian Aeronautical and Space Journal*, Vol. 29. No. 1, March 1982.
- FARMER, D.M. 1982. Summary of scientific and engineering principles in marine tailings disposal, D. Ellis (ed.). *Ann Arbor Science*, Ann Arbor, Michigan.
- FARMER, D.M. and H.J. FREELAND. The physical oceanography of fjords. In: *Progress in Oceanography*. (In press.)
- FARMER, D.M. and M. TAKAHASHI. 1982. Effects of vertical mixing on photosynthetic responses. *Jap. Journal of Limnol.*, **43**(3):173-181.
- FARMER, D.M. 1982. Stratified flow over sills: a review. In: *Proc. of Coastal Oceanography Workshop, Os, Norway, June 6-11, 1982*.
- FORBES, J.R. and M. HICKMAN. 1981. Palaeolimnology of two shallow lakes in central Alberta, Canada. *Int. Revue ges. Hydrobiol.*, **66**:863-888.
- FREELAND, H.J. 1982. A seasonal upwelling event observed off the west coast of British Columbia, Canada. In: *Proc. of Coastal Oceanography Workshop, Os, Norway, June 6-11, 1982*, H. Gade (ed.), Plenum Press.
- FREELAND, H.J. 1982. Book review of *Coastal Upwelling*, F. Richards (ed.). In: *Can. J. Fish. Aquat. Sci.*, **39** (5):804-805.

- FREELAND H.J. and K.L. DENMAN. 1982. A topographically upwelling center off southern Vancouver Island. *J. Mar. Res.*, **40**(4):1069-1093.
- FREELAND, H.J. and L.F. GIOVANDO. 1982. Unusual sea surface temperature off the Pacific northwest coast in 1981. *Coastal Oceanography and Climatology News*, **4**(2):16-17.
- GARDNER, G.A. 1982. Patterns in the distribution and abundance of selected zooplankton species from the coast of British Columbia. *Biol. Oceanogr.*, **1**:255-270.
- GARDNER, G.A. 1982. Biological and hydrographic evidence for Pacific equatorial water on the continental shelf of Vancouver Island, British Columbia. *Can. J. Fish. Aquat. Sci.*, **39**:660-667.
- GARDNER, G.A. and I. SZABO. 1982. *British Columbia Pelagic Marine Copepoda: An Identification Manual and Annotated Bibliography*, Canadian Special Publication of Fisheries and Aquatic Sciences 62.
- GARGETT, A.E. 1982. Turbulence measurements from a submersible. *Deep-Sea Res.*, **29**(9A):1141-1158.
- GARGETT, A.E. and R.W. SCHMITT. 1982. Observations of salt fingers in the central waters of the eastern North Pacific. *J. Geophys. Res.*, **87**:8017-8029.
- GRAY, D. and A.R. MORTIMER. 1982. Loran-C coordinate converters — plague or panacea. *International Hydrographic Review*, January 1982.
- HENRY, R.F. and T.S. MURTY. 1982. Tides in the Bay of Bengal. In: *Proc. of the Int. Conf. on Computational Methods and Experimental Measurements*, Washington, D.C., June 30-July 2, 1982, G.A. Keramides and C.A. Brebbar (eds.), Springer-Verlag, New York, pp. 541-550.
- HOFF, J.T., J.A.J. THOMPSON and C.S. WONG. 1982. Heavy metal release from mine tailings into sea water — a laboratory study. *Mar. Poll. Bull.*, **13**:283-286.
- LEWIS, E.L. and R.G. PERKIN. 1982. Seasonal mixing processes in an Arctic fjord system. *J. Phys. Oceanogr.*, **12**: 74-83.
- LEWIS, E.L. and R.G. PERKIN. 1982. Supercooling in surface waters of the Arctic Ocean. *Ocean Modelling*, **47**.
- MACDONALD, R.W. and F.A. McLAUGHLIN. 1982. The effect of storage by freezing on dissolved inorganic phosphate, nitrate and reactive silicate for samples from coastal and estuarine waters. *Water Research*, **16**:95-104.
- MACDONALD, R.W. 1982. An examination of metal inputs to the southern Beaufort Sea by disposal of waste barite in drilling fluid. *Ocean Management*, **8**:29-49.
- MACDONALD, R.W. 1982. An examination of metal inputs to the Arctic marine environment (Beaufort Sea) via drilling fluid disposal. In: *Report on Offshore Oil and Gas Drilling Fluid Disposal in the Canadian North* (section 3.8), prepared by an industry/government steering committee and working group (July 1982).

- MACDONALD, R.W. 1982. Environmentally acceptable trace metal contents of barite for Arctic disposal. In: *Report on Offshore Oil and Gas Drilling Fluid Disposal in the Canadian North* (section 3.10), prepared by an industry/government steering committee and working group (July 1982).
- MACKAS, D.L. and R.W. OWEN. 1982. Temporal and spatial resolution of pump sampling systems. *Deep-Sea Research*, **29**:883-892.
- MACKAS, D.L. and H. SEFTON. 1982. Plankton species assemblages off Vancouver Island: geographic pattern and temporal variability. *J. Marine Res.*, **40**:1173-1198.
- MELLING, H. and E.L. LEWIS. 1982. Shelf drainage flows in the Beaufort Sea and their effect on the Arctic Ocean pycnocline. *Deep-Sea Res.*, **29**(8A):967-985.
- MURTY, T.S. 1982. Streakiness — results of a numerical experiment. *Ocean Modelling*, **44**:8-9, 18-19.
- MURTY, T.S. 1982. Sea level. *New Scientist*, p. 313, April 29, 1982.
- MURTY, T.S., G.A. McBEAN and B. McKEE. 1982. Explosive cyclogenesis in the northeast Pacific Ocean. In: *Proc. of the 9th AMS Conference on Weather Forecasting and Analysis, Seattle, Wa., June 28-July 1, 1982*, pp. 323-328.
- MURTY, T.S. 1982. Comments on coconuts in miocene turbidities in New Zealand: possible evidence for tsunami origin of some turbidity currents. *J. of Geology*, **10**(9):p.489.
- MURTY, T.S. 1982. Comment on numerical simulation of the surge generated by the 1977 Andhra cyclone. *Quarterly Journal of the Royal Meteorological Society*, **108**(458):987-990.
- RICHARDSON, G.E. 1982. Assignment Egypt — a hydrographic survey of the River Nile. *Lighthouse*, **26**, November 1982.
- ROWE, R.D. and D.R. TOPHAM. 1982. The application of reduced scale tests for a sub-sea containment system to a hypothetical blowout case. *Second Sub-Sea Containment Workshop, Oslo, December 2-3, 1982*.
- SANDILANDS, R.W. 1982. Hydrographic surveying in the Great Lakes during the nineteenth century. *The Canadian Surveyor*, Vol. 36, No. 2, June 1982.
- SANDILANDS, R.W. 1982. Reminiscences of the Admiralty Newfoundland survey. *Lighthouse*, **26**, November 1982.
- STUCCHI, D.J. 1982. Shelf-fjord exchange on the west coast of Vancouver Island. In: *Proc. of Coastal Oceanography Workshop, Os, Norway, June 6-11, 1982*.
- TABATA, S. 1982. Oceanic time-series measurements from Station P and along Line P in the northeast Pacific Ocean. MS report, WCP-21; papers presented at the *Meeting on Time Series of Ocean Measurements, Tokyo, May 11-15, 1981*, 400 p. 171-192.
- TABATA, S. 1982. The anticyclonic, baroclinic eddy of Sitka, Alaska in the northeast Pacific Ocean. *J. Phys. Oceanogr.*, **12**(10):1260-1282.

- TAKAHASHI, M., I. KOIDE, K. ISEKI, P.K. BIENFANG and A. HATTORI. 1982. Phytoplankton species' responses to nutrient changes in experimental enclosures and coastal waters. In: *Marine Mesocosms*, Grice and Reeve (eds.), Springer-Verlag N.Y., pp. 333-340.
- THOMPSON, J.A.J. and W.D. JAMIESON (eds.) 1982. *Proc. of Symp. on Marine Chemistry into the Eighties, Victoria, May 31-June 1, 1979*. 202 pp.
- THOMPSON, K.A., D.A. BROWN, P.M. CHAPMAN and R.O. BRINKHURST. 1982. Histopathological effects and cadmium-binding protein synthesis in the marine oligochaete *Monopylephorus culiculatus* following cadmium exposure. *Trans. Amer. Microscop. Soc.*, **101**:1026.
- THOMSON, R.E. and W.R. CRAWFORD. 1982. The generation of diurnal period shelf waves by tidal currents. *J. Phys. Oceanogr.*, **12**:635-643.
- THOMSON, R.E. and S. TABATA. 1982. Sea levels in the eastern Pacific Ocean. MS report, WCP-21; papers presented at the *Meeting on Time Series of Ocean Measurements, Tokyo, May 11-15, 1981*, 400 p. 137-154.
- THOMSON, R.E. and S. TABATA. 1982. Baroclinic oscillations of tidal frequency at Ocean Weather Station P. *Atmosphere-Ocean*, **20**:242-257.
- TOPHAM, D.R. 1982. The transient response of cylindrical conductivity sensors. *International STD conference, La Jolla, February 8-11, 1982*.
- TOPHAM, D.R., G.A. GREGORY and M. FOGARASI. 1982. Calculations of the flow in the marine riser section of a sub-sea oilwell blowout collection device. In: *Proc. of the 5th Arctic Marine Oilspill Program Technical Seminar, Edmonton, June 15-17, 1982*.
- TUNNICLIFFE, V. 1982. Effects of wave-induced flow on a reef coral. *J. exp. mar. Biol. Ecol.*, **64**:1-11.
- VOSBURGH, J.A. 1982. Optimization of hydrographic survey resources. In: *Proc. CIS Centennial Convention, April 19-23, 1982*.
- WONG, C.S. 1982. Reference sea water for CO₂. In: *Proceedings of a Workshop on Oceanic CO₂ Standardization, La Jolla, Nov. 30-Dec. 1, 1979, U.S. Dept. of Energy Conf. 7911173*, H.G. Ostlund and D. Dyrssen (eds.), pp. 9-10.
- WONG, C.S. 1982. Infrared determination of total CO₂. In: *Proc. of a Workshop on Oceanic CO₂ Standardization, La Jolla, Nov. 30-Dec. 1, 1979, U.S. Dept. of Energy Conf. 7911173*, H.G. Ostlund and D. Dyrssen (eds.), pp. 32-35.

B. Department of the Environment

- McBEAN, G.A. 1982. Microscale temperature fluctuations in the atmospheric surface layer. *Boundary Layer Meteorology*, **23**:185-196.

- VERMEER, K. 1982. Food and distribution of three *Bucephala* species in British Columbia waters. *Wildfowl*, **33**:22-30.
- VERMEER, K. and L. CULLEN. 1982. Growth comparison of a plankton — and a fish-feeding alcid. *Murrelet*, **63**:34-39.

C. Department of Energy, Mines and Resources

- BASHAM, P.W., D.H. WEICHERT, F.M. ANGLIN and M.J. BERRY. New probabilistic seismic ground motion maps of Canada. *Earth Physics Branch Open File Report 1982-33*.
- CLAGUE, J.J. and J.L. LUTERNAUER. 1982. Late Quaternary sedimentary environments, south-western British Columbia, Guidebook, Field Excursion 30A. *11th Int. Congress on Sedimentology, Hamilton, Ontario*.
- CLAGUE, J.J. and J.L. LUTERNAUER. 1982. Where the river meets the sea. *Geos*, **11**: 8-12.
- DAVIS, E.E. and R.P. RIDDIHOUGH. 1982. The Winona Basin: structure and tectonics. *Can. J. Earth Sci.*, **19**: 767-788.
- DAVIS, E.E. and C.R.B. LISTER. 1982. Some contemporary marine heat flow measurement techniques and their application to contemporary geothermal problems. *Terrestrial Heat Flow Studies and the Structure of the Lithosphere, IASPEI International Workshop*, invited paper.
- DAVIS, E.E. 1982. Evidence for extensive basalt flows on the sea floor. *Geological Society of America Bulletin*, **93**: 1023-1029.
- GRANTZ, A., G.L. JOHNSON and J.F. SWEENEY. 1982. The Arctic region. In: *Perspectives in regional geological synthesis*, A.R. Palmer (ed.), D-NAG Sp. Pub. 1, Geol. Soc. Am., Boulder Colorado, 105-115.
- HODGE, D.S., D.A. ABBEY, M.A. HARBIN, J.L. PATTERSON, M.J. RING and J.F. SWEENEY. 1982. Gravity studies of subsurface mass distributions of granitic rocks in Maine and New Hampshire. *Am. J. Sci.*, **282**: 1289-1324.
- HYNDMAN, R.D. 1982. The Juan de Fuca plate map: geothermal heat flow measurement compilation and bibliography. *Earth Physics Branch*. (In press.)
- HYNDMAN, R.D., T.J. LEWIS, J.A. WRIGHT, M. BURGESS, D.S. CHAPMAN and M. YAMANO. 1982. Queen Charlotte fault zone: heat flow measurements. *Can. J. Earth Sci.*, **18**: 1657-1669.
- HYNDMAN, R.D. and D.H. WEICHERT. 1982. Seismicity and rates of relative motion on the plate boundaries of western North America. *Geophysical Journal*, **71**.
- IRVING, E. and G.A. IRVING. 1982. Apparent polar wandering paths — Carboniferous through Cenozoic, and the assembly of Gondwana. *Geophys. Surveys*, **5**: 141-188.

- JOHNSON, G.L. and J.F. SWEENEY (eds.). 1982. Structure of the Arctic. *Tectonophysics*, **89**: 357 pp.
- KEEN, C.E. and T.J. LEWIS. 1982. Radiogenic heat production in sediments from the continental margin of eastern North America: implications for hydrocarbon generation. *Am. Assoc. Petrol. Geol. Bulletin*, **66**: 1402-1407.
- LEWIS, T.J. and L. WERNER. 1982. Geothermal gradients on the west side of Okanagan Lake, B.C. *Earth Physics Branch Open File Report 82-6*: 58 pp.
- LEWIS, T.J. 1982. The assessment of low temperature reservoirs in British Columbia. In: *Proc. of Pacific Geothermal Conf., Univ. of Auckland, Part 2*: 345-348.
- McMECHAN, G.A. 1982. Resonant scattering by fluid-filled cavities. *Bull. Seism. Soc. America*, **72**: 1143-1153.
- McMECHAN, G.A. 1982. Low-velocity zone reflections observed in geometrical shadows of refraction profiles. *Geophys. Jour. R. Astr. Soc.*, **71**: 261-268.
- ROGERS, G.C. 1982. Oceanic plateaus as meteorite impact signatures. *Nature*, **299**: 341-342.
- ROGERS, G.C. 1982. Revised seismicity and revised fault plane solutions for the Queen Charlotte Islands region. *Earth Physics Branch Open File Report 82-23*: 73 pp.
- SWEENEY, J.F. 1982. Structure and development of the polar margin of North America. In: *Dynamics of passive margins*, R.A. Scrutton (ed.), *Geodynamics Series*, Vol. 6, Am. Geophys. Union, Washington, D.C.: 17-29.
- SWEENEY, J.F., J.R. WEBBER and S.M. BLASCO. 1982. Continental ridges in the Arctic Ocean: LOREX constraints. In: *Structure of the Arctic*. G.L. Johnson and J.F. Sweeney (eds.). *Tectonophysics*, **89**: 217-237.
- SWEENEY, J.F. 1982. Mid-Paleozoic travels of Arctic-Alaska. *Nature*, **298**: 647-648.
- SWEENEY, J.F. 1982. Mid-Paleozoic lateral tectonics in the Arctic. *Eos, Trans. Am. Geophys. Union*, **63**: 1125.
- WEICHERT, D.H., P.W. POMEROY, P.S. MUNRO and P.N. MORK. 1982. Strong motion records from Mirimichi, New Brunswick 1982 aftershocks. *Earth Physics Branch Open File Report 82-34*.

APPENDIX III

Permanent Staff 1982

Institute of Ocean Sciences

A. Department of Fisheries and Oceans

Director-General

Mann, C.R.; B.Sc., M.Sc. (N.Z.), Ph.D. (Brit. Col.), D.Eng. (N.S. Tech.), FRSC

Management Services Division

Chief of Division:

Todd, N.A.; B.Sc. (Glasgow), M.A. (Carleton)

Adamson, G.

Clapp, L.A.

Coldwell, J.H.

Cooper, B.J.

Curtis, J.N.

Deane, G.J.

Delacretaz, A.

Denney, C.E.

Doxey, K.

Doyle, D.A.

Drysdale, A.E.

Firth, C.

Grills, C.J.

** Hope, T.

Keding, L.M.

** Kroeger, K.

Lafortune, A.J.; B.A. (Manitoba)

Lapp, B.I.; B.A. (Victoria)

Lohrmann, B.A.; B.Sc., M.Sc. (Guelph)

Mathias, A.L.

** McKee, C.

McKenzie, S.D.

Oakfield, C.L.

** Quay, L.

* Parsons, J.E.

Perras, P.M.

Peirson, E.

Poulin, J.G.

Sabourin, J.T.

** Smith, K.R.

Thomson, L.S.C.; B.A. (Sask), B.L.S. (B.C.)

Tillie, D.G.

* Tulloch, S.P.

Van Dusen, T.S.

Van Eyk, W.J.

* *Left in 1982*

** *Joined in 1982*

Commissionaires

Sgt. W.L. Caldwell

Sgt. D.W. Price

* Comm. J. Quinton

Comm. L. Trerice

* Comm. P. Osborne

Comm. H. Moffat

* Comm. R. Alcock

* Comm. J. Redden

Comm. J. Holliger

Comm. B. Ashton

** Comm. F. Alexander

** Comm. L. Moe

** Comm. R. Morris

** Comm. W. Wilson

** Comm. L. Brown

** Comm. M. Brundrige

Personnel

Regional Personnel Manager:

Hamilton, K.R.; B.A. (Brit. Col.)

Knapp, B.M.

**McGregor, D.A.; B.A. (Victoria)

Olauson, E.J.

Smith, C.S.

Stevens, I.B.; CIMA (McMaster)

*Wenezenki, L.B.

*Left in 1982

**Joined in 1982

Hydrography

Director of Hydrography:

Bolton, M.; C.L.S.

Ages, A.B.; B.A.Sc., M.A.Sc. (Brit. Col.), P. Eng.

*Bastarache, M.; Dip. BCIT

Bell, R.D.

Browning, P.C.

Canning, B.

Chapeskie, R.

Coldham, F.A.

Collins, T.

Crawford, W.R.; B.Sc., M.A.Sc. (Waterloo), Ph.D. (Brit. Col.)

Crowley, J.V.; C.L.S.

Crowther, W.S.; (Ont. Inst. of Chartered Cartographers)

Curran, T.A.; B.A.Sc. (EE), M.Sc. (Brit. Col.), P.Eng.

Czotter, K.L.; Dip. BCIT

Dobson, D.C.

Dorosh, L.W.; Dip. BCIT

Douglas, A.; B.Sc. (Victoria)

*Dow, A.J.; P.Eng. (UNB)

Earl, E.L.P.

Eaton, G.H.; Dip. BCIT, B.Sc. (UNB)

Ellison, G.

Farmer, P.M.

Fisher, D.L.

Galloway, J.L.; B.A.Sc. (EE), M.A.Sc. (EE) (Brit. Col.), P.Eng.

Gould, J.

Halcro, K.; Dip. BCIT

**Hare, R.; Dip. BCIT

Harrison, D.W.

**Hartung, W.

Hermiston, F.V.

Hinds, E.W.; Dip. BCIT

Hohl, M.

Hollinger, C.; Dip. BCIT

Holman, K.R.

Huggett, W.S.; Master (FG), C.L.S.

Jackson, D.

Jennings, M.

Johnson, B.A.; Dip. BCIT

Kenny, B.

Kidson, G.

Korhonen, R.K.

Larkin, J.B.; B.Sc. (PEI)

Lee, K.S.

*Lichtensteiger, P.

Loschiavo, R.; Dip. BCIT

Lusk, B.M.; Master (350 T), C.L.S.

Lyngberg, K.; Dip. BCIT

Lyon, A.G.

Ma, A.C.; B.Sc. (Victoria)

Milner, P.R.; Dip. BCIT

Moody, A.E.

Mortimer, A.R.; Master (FG), B.Sc. (Victoria), C.L.S.

Muse, R.A.; Trade Cert. CAF

**Nowak, C.; Dip. BCIT

*O'Connor, A.D.; Mate (HT) (UK), Master (350 T), C.L.S.

Osborne, M.

Parks, J.R.; B.A.Sc. (EE) (Brit. Col.)

Patton, M.M.

Pflugger, H.

Philp, A.R.

Pickell, L.M.

Pierce, R.A.

Pite, H.

Popejoy, R.D.

Rapatz, W.J.; B.Sc. (Victoria), C.L.S.

Raymond, A.R.; Dip. (Algonquin College)

Redman, D.
 Richardson, G.E.; C.L.S.
 Roberts, J.W.; Master (FG), Cdr. RCN (Ret'd.)
 Ross, A.D.; CC (Ont. Inst. of Chartered Cartographers)
 Sandilands, R.W.; Lt. (H) RN (Ret'd.), C.L.S., FRGS
 Sargent, E.D.; Dip. BCIT
 Schofield, A.
 *Schofield, B.
 Smedley, A.J.; LCdr. RCN (Ret'd.)
 Smith, A.; Master (FG)
 Smith, G.R.; B.A.Sc. (ME) (Brit. Col.), P.Eng.
 Steeples, J.; Cert. Mech. Eng. (Edinburgh)
 Stephenson, F.E.; B.Sc. (Victoria)
 Taylor, R.G.
 Taylor, W.R.; Dip. BCIT
 **Tennant, M.
 Thompson, L.G.
 Thomson, A.D.; Dip. BCIT
 **Tuck, B.

Van Duin, W.P.; Dip. BCIT
 Vosburgh, J.A.; Dip. BCIT, C.L.S.
 Wakefield, L.M.
 Ward, M.M.; Dip. BCIT, B.A. (Lakehead)
 **Wardle, P.
 Watt, B.M.
 *Watt, J.V.; B.A.Sc. (EE) (Brit. Col.), P.Eng.
 Whincup, G.
 Wigen, S.O.; B.A.Sc. (Brit. Col.), P.Eng.
 ***Woods, M.V.; Dip. BCIT
 Woodward, M.J.; B.Sc. (Victoria), M.Sc. (Toronto)
 Woollard, A.; B.Sc. (Victoria)
 **Woolley, R.; Dip. BCIT
 Yee, J.

* Left in 1982
 ** Joined in 1982
 *** Educational Leave

Ship Division

Acting Regional Marine Superintendent:

Parkinson, R.W.; Engineer 1st Class Combined;
 Member, Institute of Marine Engineers

Fitch, L.A.H.; Master H.T.; Assist. Marine
 Superintendent (Deck)

Smith, F.V.; Depot Supervisor

Craton, M.; Administrative Clerk

CSS PARIZEAU

Newton, B.L.; Master F.G., Master
 Coombes, A.S.; ON I, 2nd Officer
 Loughnane, D.; Watchkeeping Mate, 3rd Officer
 *Olcen, P.; Engineer 1st Class Combined, Chief Engineer
 Pereira, P.B.; Engineer 1st Class Combined,
 Chief Engineer
 Tran, K.H.; Engineer 2nd Class Motor,
 Senior Second Engineer
 Stanway, J.D.; Engineer 3rd Class Motor,
 Second Engineer
 Palmer, S.; Supply Officer

CSS VECTOR

Sjoholm, K.; Master F.G., Master
 Wheeler, M.; ON I, 1st Officer
 Campbell, J.; Watchkeeping Mate, 2nd Officer
 Pearson, R.; Engineer 3rd Class Motor, Chief Engineer
 Burrell, R.; Engineer 3rd Class Motor, Second Engineer
 McQuarrie, I.; Engineer 4th Class Motor,
 Third Engineer

PISCES IV

Chambers, F.J.; Chief Pilot
 Taylor, R.H.; Pilot
 Witcombe, A.; Pilot
 Oszust, J.; Pilot
 *Thomas, G.; Pilot
 Holland, R.R.; Pilot
 Shepherd, K.; Pilot

CSS RICHARDSON

MacKenzie, R.W.; ON 1, Master

* Left in 1982

Ocean Information

Chief of Division:

Cornford, A.B.; B.Sc. (McMaster), Ph.D. (Brit. Col.)

*** Giovando, L.F.; B.A., M.A., Ph.D. (Brit. Col.)

** Glover, K.T.; B.A. (UNB)

Smiley, B.D.; B.Sc., M.Sc. (Alberta)

** Joined in 1982

*** On Assignment from Ocean Physics Division

Ocean Chemistry Division

Chief of Division:

Wong, C.S.; B.Sc., M.Sc. (Hong Kong), Ph.D. (Scripps),
Dip. Mar. Sc. (UNESCO), F.R.S.Chem. (U.K.), F.C.I.C.

Bellegay, R.D.; Dip NAIT, Assoc. Deg. in Oceanography
(Shoreline Community College, Seattle)

Cretney, W.J.; B.Sc., Ph.D. (Brit. Col.)

Johnson, W.K.; Dip. BCIT

Macdonald, D.M.; B.A.Sc. (Brit. Col.)

Macdonald, R.W.; B.Sc., Ph.D. (Dalhousie)

McLaughlin, F.A.; B.Sc. (Victoria)

** O'Brian, M.C.; B.Sc. (Alberta)

Paton, D.W.; B.Sc. (Brit. Col.)

Smith, G.L.; Dip. NAIT

Soutar, T.J.; Dip. BCIT

Thompson, J.A.J.; B.Sc. (McMaster),
Ph.D. (Alberta), F.C.I.C.

Whitney, F.A.; B.Sc. (Brit. Col.)

** Joined in 1982

Ocean Physics Division

Chief of Division:

Garrett, J.F.; B.A. (Harvard), Ph.D. (Brit. Col.)

Bell, W.H.; B.A.Sc. (Brit. Col.), M.Sc. (Hawaii), P.Eng.

** Bennett, A.F.; B.Sc. (U. of Western Australia),
M.S., Ph.D. (Harvard)

Bigham, R.W.

Chase, G.W.; Dip. BCIT

Cooke, R.A.; Dip. RCC

Crean, P.B.; B.Sc. (Dublin), M.A.Sc. (Toronto),
Ph.D. (Liverpool)

de Jong, C.

Farmer, D.M.; B.Comm., M.Sc. (McGill), Ph.D. (Brit. Col.)

Francis, D.B.; B.Sc. (Victoria)

Freeland, H.J.; B.A. (Essex), Ph.D. (Dalhousie)

Gargett, A.E.; B.Sc. (Manitoba), Ph.D. (Brit. Col.)

Gower, J.F.R.; B.A., M.A., Ph.D. (Cantab)

Henry, R.F.; B.Sc. (Edinburgh), Ph.D. (Cantab)

** Holloway, G.; B.A., M.S., Ph.D. (California)

Johnston, P.

Kamitakahara, G.R.; B.Sc. (Toronto)

Koppel, A.W.
Kimber, P.M.
Kuwahara, L.S.C.; B.Sc. (Brit. Col.)
Lake, R.A.; B.Sc. (Brit. Col.). M.Sc. (Washington)
Lee, A.Y.P.; B.Sc. (Victoria)
Lewis, E.L.; B.Sc., M.Sc., Ph.D. (London)
Love, J.

*** McNeill, J.M.

Meikle, J.H.
Melling, H.; B.Sc., M.Sc., Ph.D. (Toronto)
Minkley, B.G.; Dip. BCIT
Miyake, M.; B.S. (EE) (Drexel), M.S., Ph.D. (Washington)

** Moonie, J.A.

Moorehouse, S.W.
Murty, T.S.; B.Sc., M.Sc. (Andhra), M.S., Ph.D. (Chicago)

Perkin, R.G.; B.A.Sc., M.Sc. (Brit. Col.)
Richards, D.L.
Spearing, L.A.F.; B.Sc. (Brit. Col.)
Stickland, J.A.
Stucchi, D.J.; B.A.Sc. (York), M.Sc. (Dalhousie)
Sudar, R.B.; B.A.Sc. (Toronto)
Tabata, S.; B.A., M.A. (Brit. Col.), D.Sc. (Tokyo)
Teichrob, R.C.; Dip. BCIT
Thomson, R.E.; B.Sc., Ph.D. (Brit. Col.)
Topham, D.R.; D.L.C., D.C.A.E., Ph.D. (Loughborough)
Wallace, J.S.

** Joined in 1982

*** Transferred to Ship Division

Computing Services

Head:

Teng, K.; B.A.Sc., M.A. (Brit. Col.)

Douglas, A.N.; B.Sc. (Victoria)
Foreman, M.G.; B.Sc. (Queen's), M.Sc. (Victoria)

** Green, J.W.; B.Sc. (Victoria)

Johns, R.E.; B.Sc. (Victoria), M.Sc. (Brit. Col.)
Lee, D.K.; B.S. (Chosun-Korea), M.S. (Oregon)

Lee, K.S.; B.Sc. (Victoria)
Linguanti, J.; B.Sc. (Victoria)

Ma, A.C.; B.Sc. (Victoria)
Oraas, S.R.; B.A.Sc., M.A.Sc. (Brit. Col.)

Page, J.S.; B.Sc. (Brit. Col.)
Smith, L.J.; B.Sc. (Simon Fraser)

* Wharton, A.H.; B.Sc. (Victoria)
Woollard, A.L.; B.Sc. (Victoria)

* Left in 1982

** Joined in 1982

Ocean Ecology Division

Chief of Division:

Brinkhurst, R.O.; B.Sc., Ph.D., D.Sc. (London)

Denman, K.L.; B.Sc. (Calgary), Ph.D. (Brit. Col.)
Forbes, J.R.; B.Sc. (Carleton), M.Sc. (Alberta)

Hill, S.H.; B.Sc. (Brit. Col.), M.Sc. (Victoria)
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Stone, M.

B. Department of the Environment

Atmospheric Environment Service

McBean, G.A.; B.Sc. (Brit. Col.), M.Sc. (McGill), Ph.D. (Brit. Col.)

Canadian Wildlife Service

Vermeer, K.; M.Sc. (Brit. Col.), Ph.D. (Alberta)

C. Department of Energy, Mines and Resources

Pacific Geoscience Centre

Acting Director:

Law, L.K.; B.A.Sc. (Toronto), M.Sc. (U. of Western Ontario), Ph.D. (Cantab)

Administrative Group

Fyfe, K.; Head
Chisholm, D.M.
** McDonald, L.J.
** Studsrud, W.A.L.

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Bunyan, T.C.
Whitford, H.A.

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Yorath, C.J.; Head, B.Sc. (Brit. Col.), M.Sc. (Alberta),
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Bornhold, B.C.; B.Sc. (Waterloo), M.A. (Duke),
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* Kari, C.M.; B.Sc. (Carleton)

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** Bentkowski, W.; B.Sc. (U. of Western Ontario)

Gravity Group

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Price, W.

Seemann, D.; B.Sc. (Brit. Col.)

Sweeney, J.F.; B.A., M.A., Ph.D. (S.U.N.Y., Buffalo)

Seismic Hazards

Weichert, D.H.; Head, B.A.Sc., M.Sc., Ph.D. (Brit. Col.)

Gregory, M.J.

Rogers, G.C.; B.Sc. (Brit. Col.), M.Sc. (U. of Hawaii)

Horner, R.; B.Sc. (Manitoba)

Seismic Structure

Hyndman, R.D.; Head, B.A.Sc., M.A.Sc. (Brit. Col.), Ph.D. (A.N.U.)

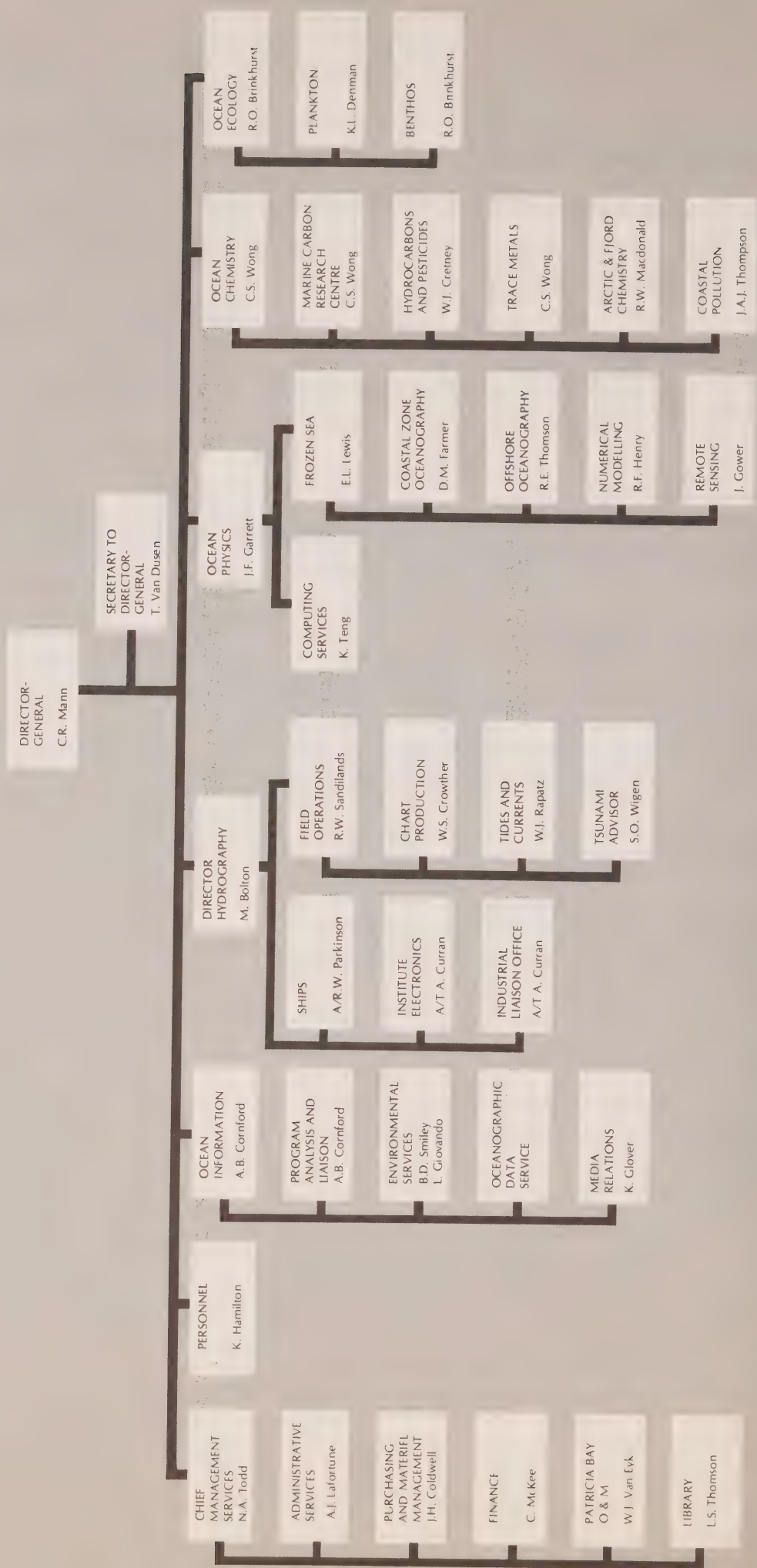
* McMechan, G.A.; B.A.Sc. (Brit. Col.), M.Sc. (Toronto)

* Left in 1982

** Joined in 1982

Organization Chart

Department of Fisheries and Oceans



**1982
ANNUAL
REVIEW
OF
ACTIVITIES**



Government of Canada Gouvernement du Canada

**Institute
of
Ocean Sciences**

PATRICIA BAY, SIDNEY, B.C.

BINDING SECT. AUG 7 1985

